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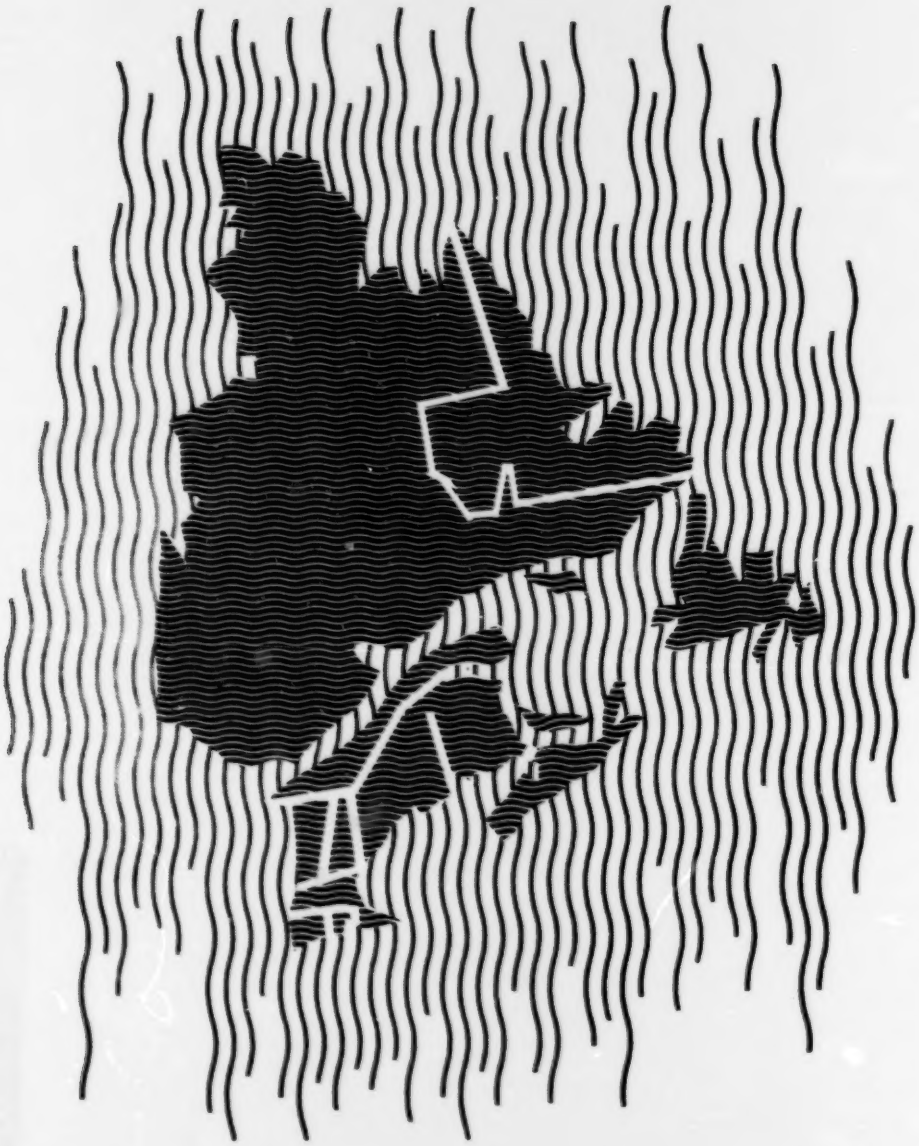
Understanding Hydronic Heating Systems



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The Conference of the New England Governors and the Eastern Canadian Premiers
Conférence des Gouverneurs de la Nouvelle-Angleterre et des Premiers Ministres de L'Est du Canada

Understanding Hydronic Heating Systems

New England Secretariat
New England Governors' Conference Inc
76 Summer Street
Boston, MA 02110 (617) 423-6900

Eastern Canadian Secretariat
Secretariat de L'Est du Canada
P.O. Box 2044, Halifax, N.S.
B3J 2Z1 (902) 424-5095

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Treizième conférènce annuelle
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de l'Est du Canada
16-18 juin 1985
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RESOLUTION 13-5

RETROFIT MANUAL

WHEREAS, by Resolution 12-11 the 1984 Annual Conference of the New England Governors and the Eastern Canadian Premiers endorsed the proposal of the Northeast International Committee on Energy to explore the establishment of specific long-term goals and programs leading to the weatherization of all structures in the region;

WHEREAS, the Governors and Premiers recognize that the extensive utilization of oil-fired hot water and steam distribution systems in the residential and small business sector is unique to the Northeastern States and the Eastern Canadian Provinces;

WHEREAS, the Governors and Premiers recognize that identifying practical energy options and procedures for implementation, can result in more efficient heating systems leading to reductions in consumption and overall operating costs;

NOW THEREFORE BE IT RESOLVED that the Northeast International Committee on Energy develop a retrofit manual to address oil-fired hot water and steam distribution systems.

ADOPTED BY THE 13TH ANNUAL CONFERENCE OF NEW ENGLAND GOVERNORS AND EASTERN CANADIAN PREMIERS on June 18, 1985

Premier Richard B. Hatfield
Co-Chairman

Governor John H. Sununu
Co-Chairman

FOREWARD

The Conference of New England Governors and the Eastern Canadian Premiers was established in 1973, when its first Annual Conference was held in Prince Edward Island. The Governors of the six New England States — Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont — and the Premiers of the five Eastern Canadian provinces — New Brunswick, Newfoundland, Nova Scotia, Prince Edward Island, Quebec — have been meeting since that time. These meetings evolved from the historic and expanding economic and cultural ties among the states and the provinces.

At their Annual Conference, the Governors and Premiers have discussed and acted on many energy issues. In 1978, the Governors and Premiers established the Northeast International Committee on Energy (NICE), comprised of senior energy officials from the eleven jurisdictions, to provide a mechanism for the continued exchange of information and joint action in energy matters.

At the Thirteenth Annual Conference held in St. Andrews, New Brunswick, in June 1985, the Governors and Premiers endorsed the NICE proposal to produce a retrofit manual to address oil-fired hot water and steam distribution systems.

The large proportion of oil-fired hot water and, to a lesser extent, steam distribution systems in existing homes is unique to the Northeastern States and Eastern Provinces. There appears to be a recent shift in weatherization programs and practices from the building shell to heating systems. A semi-technical retrofit manual should prove most useful to energy audit and advisory staff, burner technicians, and informed householders in identifying practical energy options and procedures.

The publication "Understanding Hydronic Heating Systems" was written and produced by the Province of Nova Scotia with technical assistance from the State of New Hampshire.

TABLE OF CONTENTS

Part One

OPERATION, SERVICE AND RETROFIT 9

- Introduction 9
- Upgrading Hydronic Systems 9
- Service and Installation 10

Part Two

RADIATION AND HEAT DELIVERY 13

- Introduction 13
- Heat Transfer Mechanisms 13
- Types of Radiation 13
- Maintenance Considerations 15
- Retrofit Considerations 16

Part Three

THE DISTRIBUTION SYSTEM 17

- Introduction 17
- Gravity Systems 17
- Forced Circulation 17
- Piping Arrangements 17
- Zoned Systems 18
- Distribution System Components 19
- Maintenance Considerations 21
- Retrofit Considerations 21

Part Four

CONTROL SYSTEMS 23

- Introduction 23
- Gravity Control Systems 23
- Forced Circulation Systems 23
- Boilers with Tankless Coils 24
- Controlling Temperature Override 24
- Control System Components 24
- Maintenance Considerations 27
- Retrofit Considerations 27

Part Five

THE BOILER 29

- Introduction 29
- Types of Boilers 29
- Water Passages 30
- Combustion Chamber 30
- Oil Fired Burners 31
- Boiler Pressure 31
- Boiler Expansion Tanks 32
- Additional Boiler Components 32
- Boiler Water Temperature Setting 34
- Maintenance Considerations 35
- Retrofit Considerations 36

Part Six

STEAM 39

- Introduction 39
- Steam Distribution Methods 39
- Special Steam System Components 40
- Steam Traps 41
- Retrofit Considerations 42

Part Seven

ACKNOWLEDGEMENTS 43

PART ONE
OPERATION, SERVICE AND RETROFIT

Introduction

The governments of the New England States and the Eastern Canadian Provinces provide information to homeowners and the heating industry about residential and small commercial hot water (hydronic) as well as steam heating systems. The Conference of the New England Governors and the Eastern Canadian Premiers commissioned this educational publication to improve public and industry understanding of these heating systems, their components and how they function.

This manual combines both general and technical information to convey a basic understanding of hot water and steam heating systems, the relationship among their various components and the potential for a better, more energy efficient operation. The manual will emphasize hot water heating because it is far more common than steam.

Hot water heating has long been regarded as one of the better methods of providing indoor comfort. Reliability and excellent temperature control are just two of its many advantages. Unfortunately, many current heating systems do not live up to either their comfort or energy efficiency potential. Complaints about energy costs and poor heat distribution, including overheating in some rooms and insufficient heat in others, are the most common.

Solving these and other problems requires an ability to identify malfunctions, to determine maintenance procedures, and to evaluate changes to the various components of the system.

Hydronic heating systems can be divided into four distinct but harmonious operations:

Combustion — the transfer of heat energy from oil to hot water or steam,

Distribution — the movement of this hot water throughout the building,

Radiation — the transfer of heat from the hot water to the air within the building, and

Controls — the electrical/mechanical devices which control combustion and the delivery of heat through the distribution system to the radiation.

This publication describes hydronic heating systems from the point of view of the occupant. It starts with the radiation units visible in each room, progresses through the distribution system, the controls on the system, and finishes with the boiler — that mysterious, sometimes noisy monster, in the basement. This provides a progressive approach, with each chapter building on the preceding one. Steam is discussed in a separate chapter at the end.

This heating manual describes the various types of radiation. It illustrates the most common piping arrangements, identifies the various types of boilers and strategies for their control and outlines the function of the many smaller components that combine to make a hydronic heating system.

At each stage of the manual, maintenance and upgrading of the system and its components will be discussed. These will be summarized at the end of each section.

This publication is not intended to be a comprehensive design or service manual. It will, however, provide a better understanding of existing systems, how to improve their efficiency, produce lower energy costs and greater comfort for their owners.

Upgrading Hydronic Systems

It is difficult and dangerous to generalize about the potential for upgrading a hydronic heating system. While a few service-related items will benefit nearly all systems, recommending major changes to systems without seeing them may not produce the most effective or desired energy or comfort improvements.

The age and condition of the system, the cost and availability of competing fuels, local equipment and labor costs, and a consideration of the wishes, needs or resources of the homeowner or occupants will all affect recommendations for upgrading a particular system.

By improving the understanding of how the system works, this publication will help consumers and industry make appropriate decisions on upgrading.

A hydronic heating system may need upgrading because of high energy costs, comfort problems or both.

Such comfort problems as uneven heating, cold rooms, and fluctuating temperatures can sometimes be solved by simple low cost or no cost measures: removing obstructions from radiators, bleeding air from pipes, adjusting the flow of water to individual radiators (balancing) or altering the way the controls operate. The appropriate action can best be determined by understanding the system and its components.

Consumers can reduce high energy costs by increasing the energy efficiency of the system.

Energy efficiency refers to the ratio of energy output to energy input. Based on the energy content of the fuel, the efficiency is calculated by determining the amount of heat the boiler produces from the oil consumed.

$$\text{Efficiency} = \frac{\text{Heat Output of Boiler}}{\text{Energy Input of Fuel Oil}} \times 100\%$$

When dealing with oil systems, there are two efficiencies to discuss: *steady state efficiency* and *seasonal efficiency* (sometimes called *annual fuel utilization efficiency*).

Steady state efficiency refers to the percentage of heat transfer at the boiler when the burner is operating and the boiler and heating system are at normal operating temperatures. *Steady state efficiency* is determined by measuring the amount of heat lost up the chimney. A burner technician would perform this test while tuning a burner.

The *seasonal efficiency* refers to the amount of heat transferred to the home during the heating season compared to the amount of oil consumed during the same period. The *seasonal efficiency* includes losses which can result from heat escaping up the chimney when the burner is not operating, or from the build-up of soot on the boiler's heat exchange surfaces which reduce heat transferred within the boiler over the winter.

Test procedures have been developed to estimate the *seasonal efficiency* of new boilers. This information is available in the United States. Consumers should use it to compare the efficiency of different boilers.

Changes should be made to any system with a low efficiency rating. A number of options are available: upgrading the current oil burner, replacing the burner, and installing a new burner and boiler combination. Each involves different costs and benefits. Changes to the control or distribution system, such as zoning or the addition of a circulation pump or pumps, are other major cost items.

Decisions on these issues are never simple. They can not always be made simply on economic grounds. Before deciding to add a new oil burner, for example, consumers should assess the reliability of the current boiler. It is better to replace both if the boiler may not last more than a year or two. But why replace a good boiler with about ten years of service left when a new burner is one-quarter of the cost?

The reader will find ideas about upgrading and servicing of hydronic systems at the close of each chapter. The servicing of oil burners is not covered in great detail because of the many excellent publications available on the subject.

Most homeowners make a major investment in their heating system only once or twice during the life of a home. Therefore, it is important to select a good, high efficiency boiler or burner.

Homeowners are advised to get several opinions and cost estimates from contractors and suppliers and to contact their government energy office for advice and assistance.

Installing and Servicing Hydronic Heating Systems

Several diverse skills and trades install and maintain hydronic heating systems. It is important to understand the responsibilities of each of them.

Before a house is built, a qualified engineer or technician should design its heating system. The heat loss of the home must be correctly calculated with the heating system designed to match the maximum amount of heat the home will lose on the coldest day of the year. The boiler must be sized accordingly, the radiators or baseboard heaters specified on a room-by-room basis, and the proper piping and controls recommended.

If all calculations are performed correctly, with the house built as planned and the heating system installed as designed, the house should be comfortable. Unfortunately, many heating systems do not perform as they should for a variety of reasons.

Such problems as poor heat distribution often appear after the home is built. Heating costs may also be higher than expected. Heating systems are often altered without the services of a qualified heating-system designer during renovations or additions. When problems occur during the cold season, the boiler often incorrectly gets the blame.

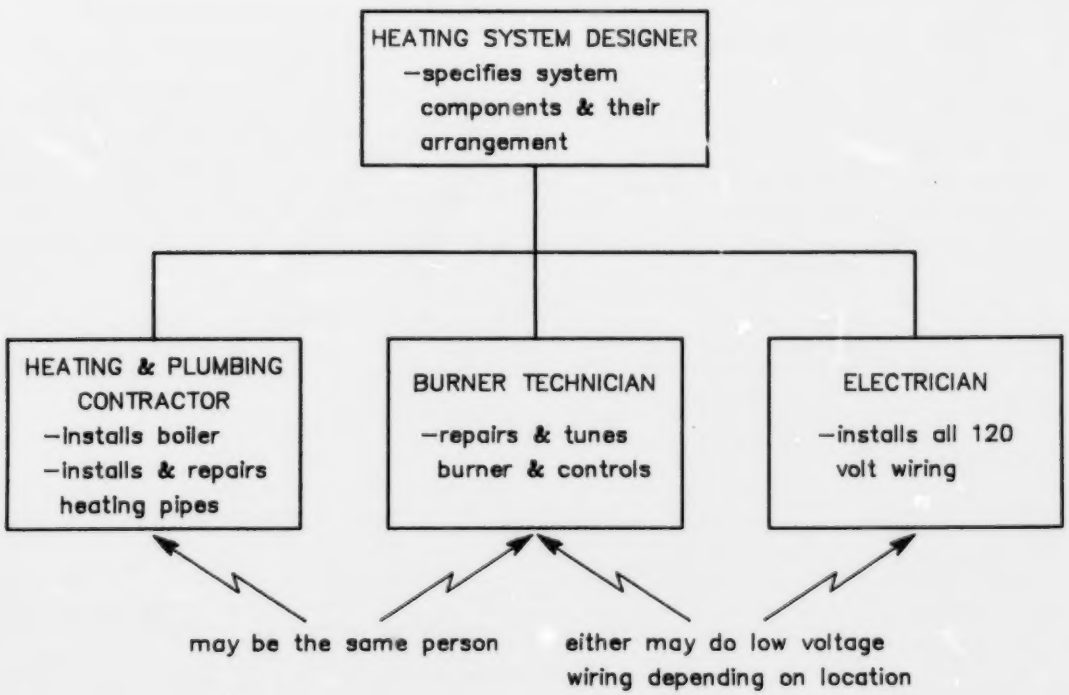

HEATING SYSTEM DESIGNER
—specifies system components & their arrangement
HEATING & PLUMBING CONTRACTOR
—installs boiler
—installs & repairs heating pipes
BURNER TECHNICIAN
—repairs & tunes burner & controls
ELECTRICIAN
—installs all 120 volt wiring
may be the same person
either may do low voltage wiring depending on location

FIGURE 1: TRADES INVOLVED IN HYDRONIC HEATING

At least three primary trades install and service the systems after they have been properly designed: plumbing and heating contractors, electricians and burner service technicians.

In urban areas where building, plumbing and electrical codes are strictly enforced, the dividing lines among the various trades are clear. In rural areas, the distinctions among the trades may be less clear. It is not uncommon for one trade to refuse to do a specific job under the jurisdiction of another trade (although they may be capable and on the scene). They may fail to point out problems that are the responsibility of another trade (although they may be aware of them and know how to fix them). Generally, each trade tries not to interfere with the other's area of work. This can be confusing and expensive for the homeowner who may not be aware of the exact problem and may call the wrong trade to fix it.

Plumbing and heating contractors work with the boiler and the distribution system: the boiler itself, the water supply to the boiler, the expansion tank, the piping between the boiler and the radiation, the radiation itself and several smaller related components.

Electricians are generally responsible for any 120 volt wiring. They always wire to the disconnect switch near the boiler but may leave the wiring of the controls to the burner technican.

The burner technician handles the burner itself and any components that affect its operation. These include the combustion side of the boiler, the metal breeching between the boiler and the chimney, the low voltage controls and the oil tank and delivery pipe (Figure 1).

In addition, chimney sweeps and bricklayers are involved in installing and maintaining the system.

PART TWO

RADIATION AND HEAT DELIVERY

Introduction

Radiation is available in a wide range of styles and sizes. The term radiation refers to the part of the heating system that actually delivers heat to the home: baseboards, convectors, radiators or radiant heating panels. Radiation transfers heat from water heated by the boiler to air and objects in the home in three ways: convection, conduction and radiant heat transfer. Some types of radiation use more than one method of heat transfer (Figure 2).

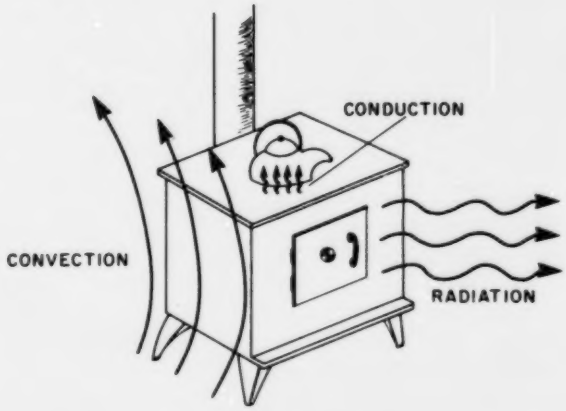


FIGURE 2: METHODS OF HEAT TRANSFER

Heat Transfer Mechanisms

Convection refers to the movement of heated air. As air adjacent to a radiator or baseboard is warmed, it becomes more buoyant. The heated air's density relative to the surrounding air drops allowing the heated air to rise. Cooler, denser air flows in to take its place. The result is a gentle movement of heated air rising from the radiation and flowing across the room and cool air moving along the floor towards the radiation.

Conduction, the movement of heat energy within a substance, results from the difference in temperature. Heat is conducted within elements of the heating system. Heat from the combustion gases is conducted through the heat exchanger wall of the boiler to the water inside. Similarly, heat from the water or steam is conducted through the pipes and radiator to the air inside the house. Regarding heat delivery to the house, conduction is not as significant (or controllable) as convection.

Radiant Heat Transfer or thermal radiation is the process of exchanging heat energy directly from one body to another without heating the intervening space. This is how the sun warms objects on earth. Thermal radiation leaves the surface of the radiant body, in our case the hot radiator or baseboard, and travels in a straight line to warm cooler objects in the room. Radiation does not heat air directly. It heats objects or surfaces which in turn heat the surrounding air by conduction and convection.

Early cast iron radiators delivered most of their heat by thermal radiation, the rest by convection. The tall convector units and modern baseboard heating deliver most of their heat by convection. Radiant floor and ceiling heating units deliver almost all their heat by thermal radiation.

Types of Radiation

Radiation has evolved from the early free standing cast iron variety to the modern convector baseboard type. Each has its own unique characteristics.

Cast Iron Radiation

Cast iron radiation is found mainly in homes built before the mid-1950s, although it was sometimes installed in the 1960s.

Cast iron, large tube column radiators date back from the early 1900s. These very large, free standing units were sometimes decorative in appearance. Many are still used today. This type of radiation emits roughly one-half of its heat from thermal radiation and the rest by convection. This type of unit has a large water capacity, requires a long time to heat and a long time to cool. This often produces "temperature over-ride" in spring and fall, when the large volume of hot water and radiation can heat a room or area to a temperature well above the thermostat setting (Figure 3).

FIGURE 3: LARGE TUBE CAST IRON RADIATOR

Cast iron small tube column radiators were popular from the 1940s to the 1960s. Often referred to as "new style", they ranged in heights from 20 to 38 inches (50.8 to 96.5 cm). Because of smaller tubes, they contain less water and provide more accurate temperature control. Their smaller size is also an advantage (Figure 4).

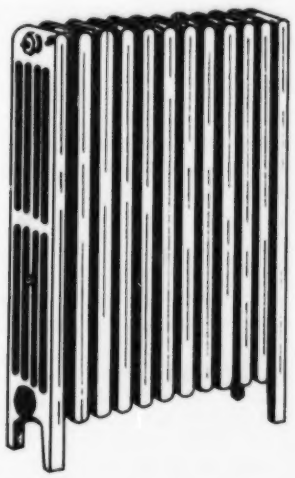


FIGURE 4: SMALL TUBE CAST IRON RADIATOR

Cast iron baseboard radiation is hollow and holds a much larger volume of water than the modern copper tube, convector baseboard units. Like all baseboard radiation, it requires less space than free standing radiation. The cast iron baseboard is more quiet than the copper baseboard and can operate effectively at water temperatures as low as 140 degrees F (60°C). Material costs tend to be high. The baseboard is manufactured in short sections which must be assembled on site (Figure 5).

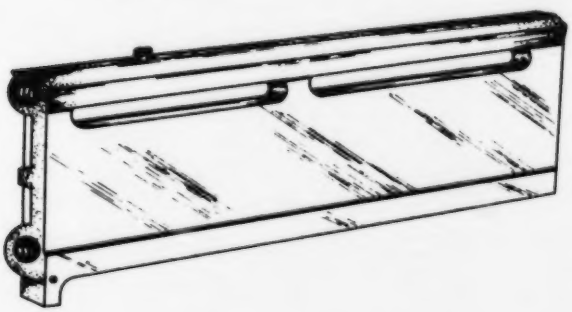


FIGURE 5: CAST IRON BASE BOARD RADIATION

Convection Radiation

Convector radiators consist of a heating element composed of a small number of pipes or tubes with a small header at each end. The tubes pass through aluminum fins. This creates the convection effect and helps conduct heat from the water or steam to the surrounding air by providing a larger surface area than the tube alone.

A metal cabinet encloses the heating element which enhances convection by producing a chimney effect. Cold air enters at the bottom, heats, and exits at the top.

A wide selection of enclosures are available, including fully recessed, semi-recessed and fully exposed units. When properly designed, the heat loss for each room is calculated and the corresponding convector capacity and physical enclosure size selected. Popular from the 1940s to the 1960s, high material and labor costs have greatly reduced the use of convector radiators in new homes. They are often necessary in confined areas such as bathrooms and vestibules where the walls are not long enough for baseboard radiation. In many cases, this type of radiation is custom ordered from the manufacturer (Figure 6).

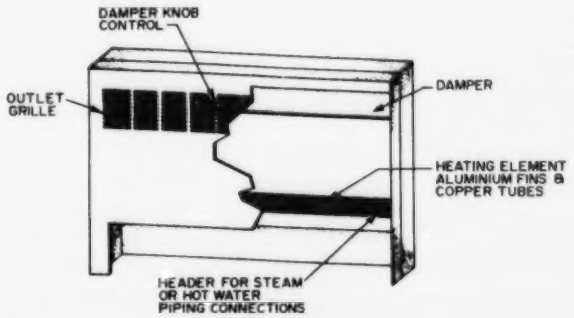

DAMPER KNOB CONTROL
OUTLET GRILLE
DAMPER
HEATING ELEMENT ALUMINIUM FINS & COPPER TUBES
HEADER FOR STEAM OR HOT WATER PIPING CONNECTIONS

FIGURE 6: CONVECTOR RADIATOR

Convector baseboard radiation is the most popular form of hot water radiation on the market today. It is made of a finned copper tube with sheet metal back and front. As with other types of radiation it is best installed on an outside wall to provide even heat distribution throughout the room.

The fins provide a large surface area to transfer heat to the air. The metal enclosure, open at the bottom and top, creates a chimney effect to aid air flow. Tube diameter, fin size and spacing, and enclosure heights all effect the heat output.

Most domestic baseboard heating uses ¾ in. (2 cm) copper tube. Higher heat output baseboard found mainly in commercial applications, use 1 in. (2.5 cm) or 1¼ in. (3 cm) copper tubing or more than one row of tube. Older homes with high ceilings and higher than average heat loss may require this high capacity baseboard in retrofit installations.

The ideal water temperature for convector baseboard is 170 degrees to 200 degrees F (77 to 93°C). This type of radiation is manufactured in a variety of lengths, ranging from three to eight feet (.9 to 2.4 m). Most types are available with movable dampers in the cabinet. Closing the dampers restricts the air flow, reduces heat output and provides a way to correct slight imbalances in the heating system or to vary the temperature among rooms (Figure 7).

Radiant Heating

Radiant heating systems consist of loops of serpentine copper tube, each fed from a common header, and embedded in the ceiling and/or floor. As the ceiling and/or floor is heated, thermal radiation flows from its surface to cooler objects in the room. The air in the room is heated when it contacts the heated surfaces and objects in the room.

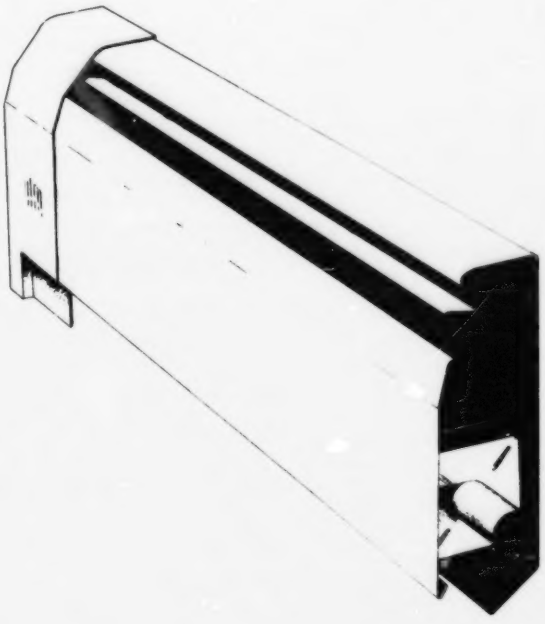


FIGURE 7: CONVECTOR BASEBOARD

Radiant heating systems often require sophisticated and accurate controls. When both floors and ceilings are heated, water temperature differences between the floor and ceiling must be accurately maintained by thermostatic, three-way mixing valves. Within each ceiling or floor system, balancing valves are needed to ensure equal flow through the various loops (Figure 8).

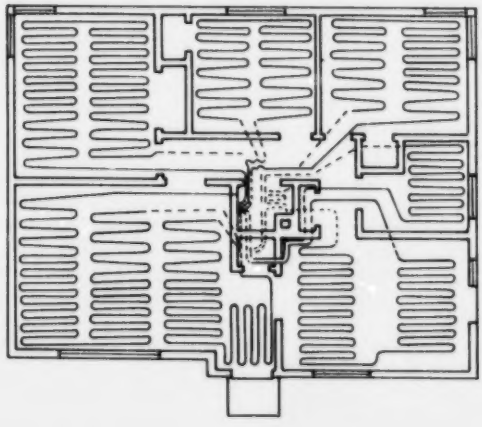
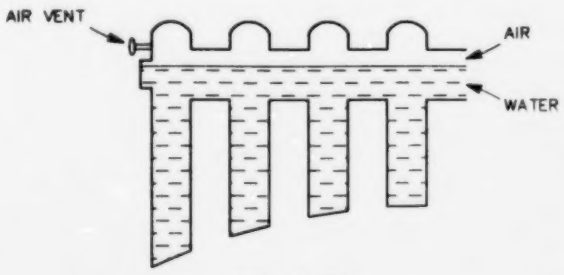


FIGURE 8: TYPICAL RADIANT HEATING LAYOUT



SIDE VIEW

FIGURE 8A: AIR TRAPPED IN A RADIATOR

Maintenance Considerations

Maintenance of the heat delivery system, or radiation, is generally the homeowners' responsibility. It is a simple task that most often requires only good housekeeping.

• **Air Removal** — All radiation should be purged of air at the start of each heating season and at other times as required. This is done by bleeding the air from each piece of radiation. The air is replaced by water from the boiler. Some systems have automatic air vents. These require no attention.

Most radiators, convectors or baseboards have air vents located at the high point of the piping. Cast iron systems often have a manual air vent which looks like a miniature tap or valve. Convection units usually have a screw that opens the vent. It is accessible with a long screwdriver through the front cover. Baseboard systems may have a manually operated miniature tap or an automatic bleed device of a disk or float-type design. Radiant heating systems are bled at the header which feeds the serpentine loops.

Regardless of the type of system, the procedure for removing air from manual valves is the same. The device should be left open until all air has escaped and closed when water appears. This procedure must be repeated for each unit of radiation. When bleeding the system, take care to avoid scalds from hot water jetting from the bleeder valve after the air has escaped (Figure 8a).

Occasionally systems are installed without any bleed devices to reduce costs. These systems are purged by applying domestic line pressure and opening a drain valve. This is a poor practice as it introduces oxygen-rich water. It is less likely to be bled annually because a plumber is required.

• **Air Flow** — Good air flow must be maintained around radiators, convector units and baseboards. Homeowners should be wary of putting items on top or in front of radiation which could restrict heat delivery. If the homeowner can not avoid placing furniture in front of radiation he should at least keep it several inches from the radiation to permit adequate air flow.

• **Radiator covers** — Covers on top of cast iron radiators restrict convective air flow. When wood covers are used, a large opening is needed in the top and a cold air opening in the bottom. Homeowners often have metal mesh enclosures built to hide the radiator. Even these covers may reduce heat output by 30 per cent or more. For an effective distribution system remove these covers.

• **Cleaning** — The fins of convection and baseboard units should be kept dust free. Most baseboards have easily removable front covers. The fins may be cleaned with a soft brush vacuum cleaner attachment. Take care not to bend the fins.

• **Painting** — Painting radiators is sometimes necessary but the final coat of paint can affect heat output. Oil paints of any color give about the same results as an unpainted, black or rusty surface. Aluminum or bronze paint will reduce the heat output.

Retrofit Considerations

When remodeling or adding to older homes care must be taken when mixing types of radiation. Some types are not compatible because of the differences in water volume and heat transfer surface area. As a result, each type of radiation has a different heat response time. Different types of radiation should only be used on separate zones with separate circulators or zone control valves and thermostats.

Whenever renovations or home additions are planned, a competent heating system designer should be consulted. They will determine the boiler operating parameters, size the radiation units, recommend the piping sizing and arrangement, and specify all the necessary components.

PART THREE

THE DISTRIBUTION SYSTEM

Introduction

The distribution system carries the heated water from the boiler to the radiation and back to the boiler. It consists mainly of iron piping or copper tubing and includes all fittings, valves and pumps. In all residential hydronic heating systems, the water (or antifreeze*) is circulated over and over again, year after year.

Water can be made to flow through the systems by gravity or forced circulation. Four basic piping arrangements are used singly and in combinations. The combination of piping arrangement and water circulation significantly affects the system's cost and comfort.

* Antifreeze is sometimes added to the water to prevent freezing. Homeowners who leave their homes unoccupied for long periods in the winter are the most common users. If the boiler stops for a long period because of a power failure or other problem, antifreeze prevents freezing in the heating system piping.

Gravity Systems

Many older heating systems rely on gravity (or thermosyphon) to circulate water from the boiler to the radiation and back to the boiler. Gravity systems work on the principle of difference in water density at different temperatures to create circulation. As water is heated, it becomes less dense (lighter) and moves from the boiler to the radiation where heat is released to the room. As the water cools, it becomes dense (heavier), and returns to the boiler. The cycle repeats; slowly, quietly, without moving parts.

Because of the slight difference in density between heated and cold water in the heating system large diameter piping is used to avoid friction developing in the distribution system. At the boiler, the pipe sizes are larger. They gradually get smaller as each radiator is supplied with hot water. Piping is carefully sloped to prevent any low points, air pockets or other impediments to the natural flow of water. For proper circulation all radiators must be located above the boiler.

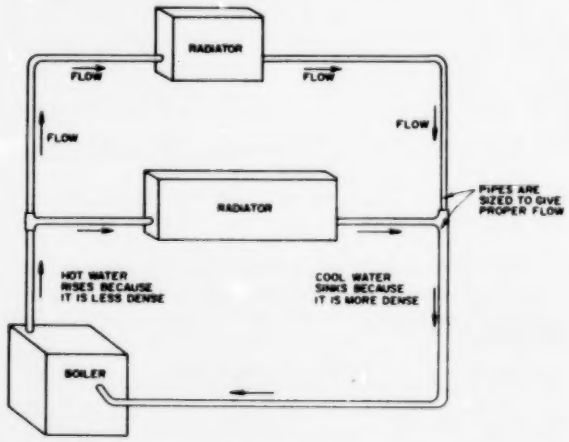


FIGURE 9: GRAVITY SYSTEM

Large pipe sizes and large radiators in gravity systems mean a large water volume that takes considerable time to heat and cool once heated. This may create overheating in spring and fall when only a small amount of heat is required (Figure 9).

Forced Circulation

Electric circulating pumps are also used to force hot water through the distribution system. This circulation form quickly delivers heated water to the radiation. These systems respond much better to temperature control than gravity systems. They also permit the use of smaller pipe sizes because friction is less of a problem. Radiation units can be located at any level (Figure 10).

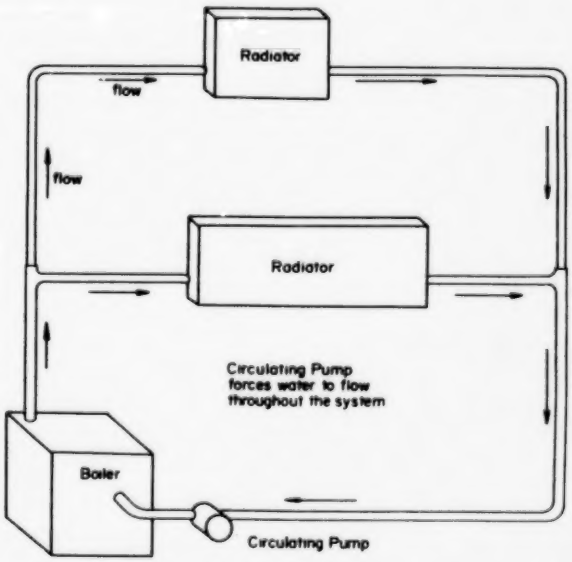


FIGURE 10: FORCED CIRCULATION SYSTEM

Piping Arrangements

The simplest distribution system is the *single pipe series loop*. Water from the boiler flows through each piece of radiation in a continuous loop before returning to the boiler. As the water moves through the system, its temperature decreases — an important consideration in determining the amount of radiation for each room. This system has a low material cost (Figure 11).

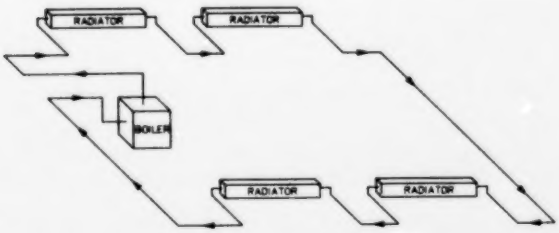


FIGURE 11: SINGLE PIPE SERIES LOOP

A second type of single pipe system makes use of *diverting fittings*. These fittings create a pressure drop, diverting some of the water flow to a branch pipe feeding a separate piece of radiation. In these systems, water temperature also decreases as the water moves around the loop. With diverting fittings, valves can be installed to control the flow of water to individual branches (Figure 12).

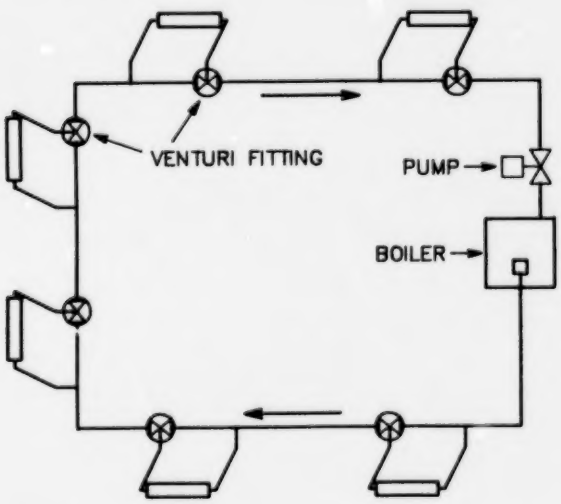


FIGURE 12: SINGLE CIRCUIT, VENTURI OR DIVERSION SYSTEM

The last two types of systems use separate supply and return pipes. In a *simple return system*, often called a "two pipe" system, water leaves the boiler and flows to the first radiator. Some water enters this radiator and returns to the boiler while the remaining water flows to the second radiator where a similar procedure is followed. The amount of water delivered to each radiator depends on the friction in the pipe and the radiation. If care is not taken in the design, most of the water will flow through the first piece of radiation and back to the boiler.

In a properly designed simple return system, the piping near the boiler is larger than the pipes supplying individual radiators. The size of pipe used to connect each radiator should vary according to the heating load and the distance from the boiler. Valves are usually used to provide added control of water flow in a simple return system (Figure 13).

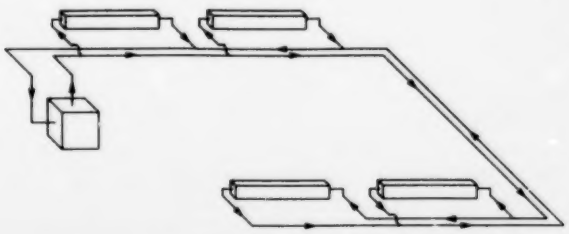


FIGURE 13: TWO PIPE – SIMPLE RETURN

The *reverse return system* provides an even flow to each piece of radiation by making the pipes to and from each radiator the same total length. In this system, the radiator nearest the boiler has the shortest length of hot water supply piping and the longest length of return piping. The radiator one-half way between the closest and farthest radiators has supply and return pipes of equal length. The radiator farthest from the boiler has the longest supply pipe and the shortest return pipe. Each route has the same total length of piping.

Because of the extra piping, this arrangement, while providing an even flow and excellent comfort and performance characteristics, is the most expensive to install (Figure 14).

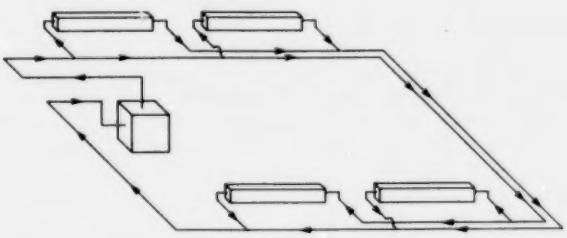


FIGURE 14: TWO PIPE – REVERSE RETURN

The type of system installed depends on the size of the building and the degree of the control required. A small bungalow may have a single pipe system. A larger, two-storey home may have two zones, with each zone a simple single pipe system. A set of flats may have multiple reverse return zones.

Zoned Systems

Most modern hydronic heating systems have several zones for separate temperature control in specific areas. Two-storey homes often have one zone for the upper floor and one for the lower floor. Most homes do not have more than four zones.

Each zone is usually a small single pipe series loop, controlled by a separate thermostat. The thermostat can operate either a circulator for each zone or one circulator and separate zone control valves for each zone (Figure 15).

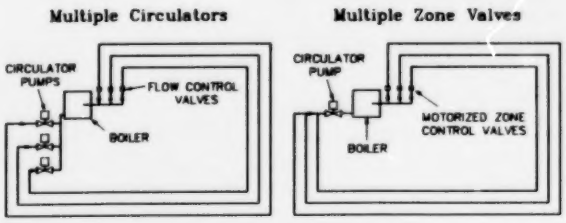


FIGURE 15: ZONED DISTRIBUTION SYSTEM

Distribution System Components

The distribution system has several key components, of which piping is the most obvious.

Piping — Threaded: Older homes, primarily those with cast iron radiators, usually have threaded pipe. Threaded pipe is made from steel with fittings of cast iron or maleable steel.

Piping — Copper Tubing: Modern installations use copper tube. Tubing is measured by its outside diameter. Copper tube is available in two wall thicknesses: thin-walled, type "M" tube is intended for low pressure applications such as heating systems, and thick-walled, type "L" is used for higher pressure domestic water application in the rest of the home.

Copper tube is joined with fittings slightly larger than the tube itself. These push-on fittings are soldered to the tube with a lead-tin solder. Cast-copper fittings made for drainage systems should not be used.

Fittings: Most fittings used in hydronic heating systems, whether for copper or threaded pipe, consist of tees, elbows, reducers, etc.

Venturi Fittings: The diversion or venturi fitting is usually found in single pipe systems.

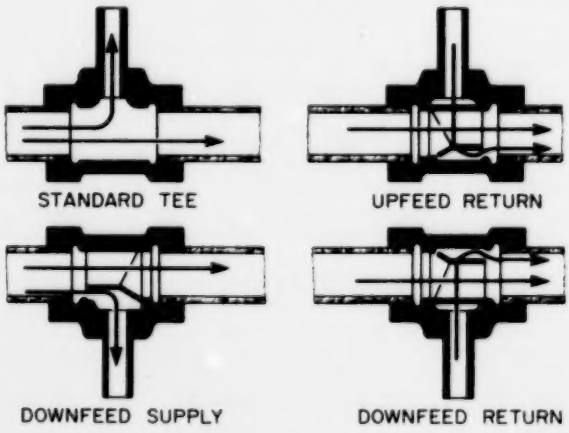


FIGURE 16: DIVERSION OR VENTURI FITTINGS

On the outside it looks like any other fitting except for a small arrow indicating the direction of flow. An internal baffle enables the fitting to divert part of the water flow in a second direction. The exact amount of water diverted can be accurately determined based on the velocity of water in the main pipe.

In most cases, one venturi fitting per radiator will provide sufficient diversion capacity. But two fittings are needed with unusually long pipe runs or large-size and high-resistance radiators. Down-fed radiation (below the main) always requires two fittings; one on the supply pipe and one on the return pipe.

These fittings permit the use of smaller sized pipes (Figure 16).

Valves: Gate or ball valves are used to facilitate repair or provide flow control. (Globe valves, common in the supply piping to the boiler, are not found in the distribution system. They provide considerable resistance to flow.)

Gate valves contain a metal gate which rises to open and drops to close the opening, like a dam on a stream. These valves are ideal for hot water heating because, in the open position, they produce little friction through the valve body. The valve can be partially opened for a predictable amount of flow control (Figure 17).

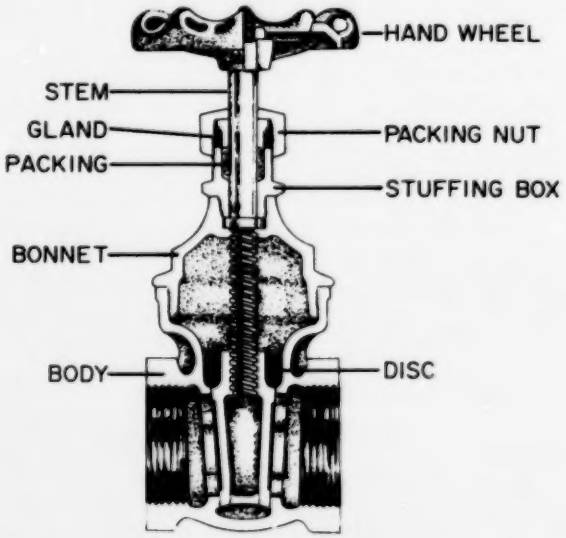


FIGURE 17: GATE VALVE

Ball valves have a spherical closure that rotates to open or close. A one-quarter turn is all that is required between the full open or closed position. In newer installations, the ball valve has replaced the gate valve because of low cost and similar performance (Figure 18).

Square head cocks are internally similar to ball valves except that a square head replaces the handle. Since a wrench is required to change the position of these valves, they are less likely to be tampered with.

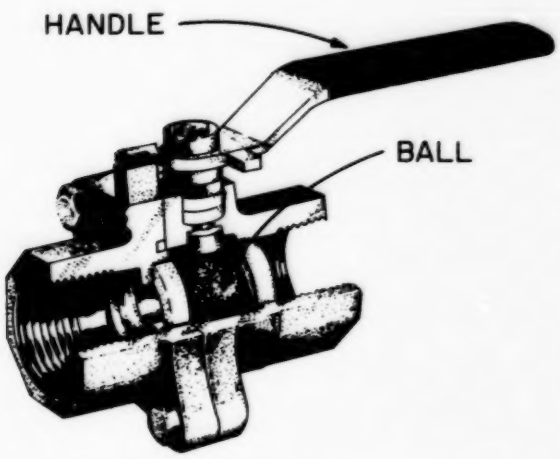


FIGURE 18: BALL VALVE

A **flow control valve** in the water supply main prevents the water from circulating through a forced circulation system by gravity when heat is not required. When the circulator starts, the valve is pushed open by the force of the water. It closes when the circulator stops. These valves are necessary on boilers which also heat domestic water.

Flow control valves are used on each zone in applications where separate circulators instead of zone valves are used for zoning. Systems with zone control valves do not require a flow control valve, as the zone control valve stops gravity circulation.

Flow control valves require no maintenance or lubrication. But after several years, they may stick in the open or closed position. These valves should be serviced by a qualified serviceman should problems occur (Figure 19).

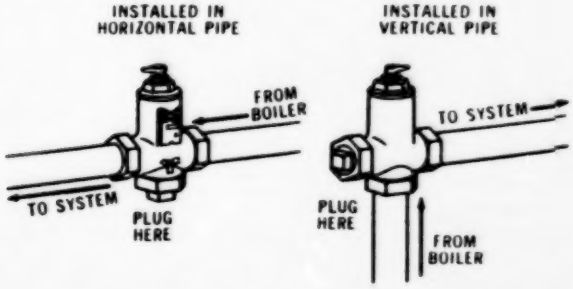


FIGURE 19: FLOW CONTROL VALVE

Automatic zone valves are used to control the flow of water or steam to a specific area or zone in the building. The valve bodies, closures and motors are available in a number of configurations. A small motor mounted on top of the valve opens and closes the valve as required. Typically, the thermostat calls for heat, the valve motor is energized; it opens the valve. The valve remains open until the area or zone to be heated has reached the required temperature.

Most new zone control valves contain a small auxiliary switch. As the motor opens the valve, the switch closes automatically and operates the circulator. When the valve closes, the switch opens and the circulator stops.

Many of the older valves require a few drops of oil annually. Most of the more modern valves have sealed bearings and require no lubrication. Most valve motors can be removed and replaced without draining the heating system. Many valves also have a small lever to open the valve manually (Figure 20).

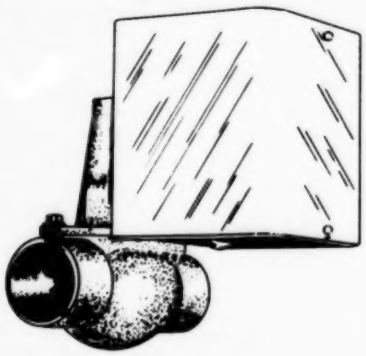


FIGURE 20: ZONE CONTROL VALVE

Hot Water Circulators. The circulator is simply an electrically operated centrifugal pump which circulates hot water throughout the system. It is usually installed on the return main, close to the heating boiler. In the past, circulators were often installed for each zone. This is still common on commercial applications where long piping runs and a high pumping capacity are required. On the more modern domestic systems, one circulator is usually installed with an automatic zone valve for each zone.

If the circulator is making abnormal noises, it is possible that the spring coupling between the motor and the circulator is worn and needs replacing. If the burner is operating properly and the water temperature is normal but the radiation does not get hot, a broken coupling is often responsible. This will not occur with some newer models as they are coupled directly.

Circulators come in a wide variety of pumping capacities. Care must be taken to replace damaged circulators with ones of proper capacity. A model that is too small will not circulate the proper volume of water and the heat output of the system will drop. If the capacity of the circulator is too great, annoying velocity noises may occur in the piping system.

Expansion Compensators. The thermal expansion and contraction of heating piping can cause serious noise problems and, in severe cases, pipes or fittings may break. For example, a 40 ft. (12 m) length of copper pipe can increase more than one-half inch (13 mm) in length when heated from room temperature to 200°F (93°C). The installation of expansion compensators in the pipe can absorb this expansion.

These devices usually consist of a corrugated metal bellows or two pieces of telescopic pipe connected with a water tight seal (Figure 21).

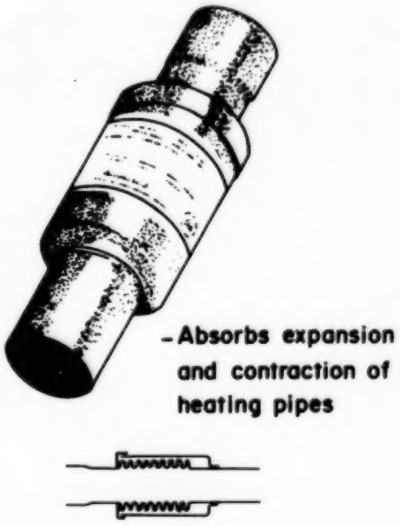


FIGURE 21: EXPANSION COMPENSATOR

Neoprene Sleeves: Neoprene sleeves can be installed around piping to reduce any squeaking noises from thermal expansion which is caused when pipes pass through a wall or partition. These simple, low cost devices significantly contribute to the homeowner's satisfaction.

Maintenance Considerations

The distribution system requires little maintenance unless a component fails. Balancing the system is a major adjustment to the distribution system.

• **Balancing the System** — Balancing the system can often correct uneven heating in a home. This process restricts the flow of water to one or more radiators while maintaining or increasing the flow to others. In this way, the heating system can be tuned to provide the required amount of heat in each area.

Balancing involves a certain amount of trial-and-error. Homeowners may be better able to balance a system than a service technician who spends little time there.

Before balancing the system, make sure the system is free of air. Check that heating problems are not the result of covers or articles piled on radiators, dust, furniture located in front of the radiator, etc.

If the cold area seems to be an entire heating zone, the piping in the basement should be checked to make sure gate, square head, or ball valves are open and not restricting the water flow. Check the operation of the circulator or zone control valves to make sure hot water is flowing through properly. Simply touch both the supply and return pipes to determine this.

When it has been determined that water is reaching the radiators in the cool areas, the flow of water to the radiator units within the comfortable or overheated areas can be restricted. This will give the cool areas more time to heat before the thermostat is satisfied.

The flow of water to radiators is restricted by partially closing the hand wheel valve by turning it clockwise. Air dampers on baseboard convector units can be closed and valves on the distribution system partially closed.

External factors such as outdoor air temperature, wind velocity and the amount of sunshine can make balancing difficult. They can affect the temperature in individual rooms of a heating zone at different times of the day or year. With patience and minor changes made one at a time, balancing can greatly improve overall comfort.

Retrofit Considerations

The conversion of gravity systems to forced systems — by adding a circulator — is the most common change.

Forced Circulation — Adding forced circulation can result in quicker temperature response, improved distribution to radiators furthest from the boiler and reduced temperature "override" or over heating during mild weather.

The conversion is simple. It involves the installation of a circulator and changes to the control components and wiring. The circulator should be carefully selected by a competent heating technician. Many of the gravity systems found in large older homes may require a high-capacity circulator pump to overcome the friction within the piping and radiators.

Some of the old cast iron, gravity systems have an expansion tank, open to the atmosphere located high in the building. Atmospheric pressure tanks should be replaced with pressurized units. An appropriate pressure reducing feed water valve should be installed.

• **Zoning the System** — Once a circulator has been added, zoning provides further temperature control. This can lead to lower heating costs. But zoning can be expensive and is not always justified based on energy savings. It will, however, improve comfort in most cases.

When temperatures can not be adequately controlled by balancing a one zone system, zoning may be the only way to ensure the desired heat distribution throughout the home.

The difficulty and cost of adding a zone or zones to a single zone system depends largely on the nature of the current distribution system. Before making a decision on zoning, sketch the piping, showing water flow. Then consult a qualified heating contractor.

PART FOUR
CONTROL SYSTEMS

Introduction

The control system operates the various parts of the heating system such as the burner and circulator. It turns them off and on as required and insures their safe operation. The number and type of controls on a particular heating system depends on its complexity: whether it has a circulator or circulators, a tankless coil for heating domestic water, one or more zones, etc.

This section describes the basic control methods. It details individual components, and outlines maintenance and upgrading considerations.

Gravity Control Systems:

The simplest control systems are found on gravity heating systems. When the thermostat calls for heat, the burner is energized. It continues to operate until the thermostat is satisfied or until the boiler water becomes too hot. When this happens a shut-off switch stops the burner.

Hot water continues to flow to the radiators after the burner stops. This often overheats the living space.

If the maximum temperature cut-off switch, called the high limit aquastat, stops the burner, it restarts when the boiler water cools, provided the thermostat still calls for heat. Otherwise, it stays off until the thermostat calls for heat (Figure 22).

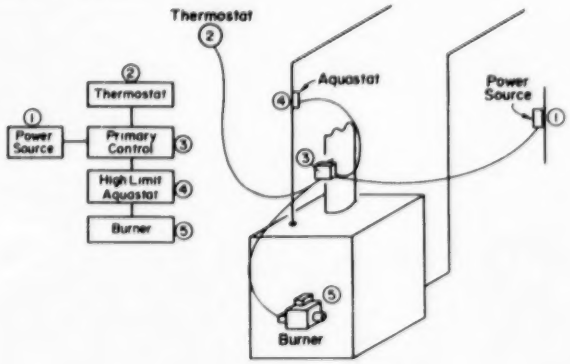


FIGURE 22: GRAVITY SYSTEM CONTROL SCHEMATIC

Forced Circulation Systems:

Systems with circulator pumps can be controlled in one of several ways. In *single zone systems*, the thermostat calls for heat and energizes the burner and circulator. The burner operates if the water temperature does not exceed the high limit aquastat setting. The circulator also operates as long as the thermostat calls for heat and the water in the boiler remains sufficiently hot. A thermostatic switch called the low limit aquastat prevents the circulator from operating when the boiler water falls below a preset temperature. The circulator will resume operation when the burner raises the water temperature if heat is still required. This low limit control is especially important for convector baseboard radiation systems which require high temperature water (Figure 22a).

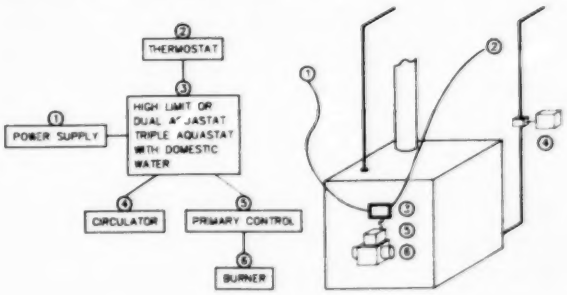


FIGURE 22A: CONTROL SCHEMATIC SINGLE ZONE SYSTEM

On *zoned heating systems with multiple circulating pumps*, each zone has a dedicated thermostat which controls the appropriate circulator. The circulators can operate simultaneously or singly.

Zoned systems with one circulator and several zone control valves operate differently. Each thermostat controls its zone control valve. Each valve incorporates a pair of switch contacts to energize the circulator and burner through the aquastat control when the zone control valve opens.

In zoned systems, the burner operates if at least one thermostat calls for heat and the boiler water is not hot enough to trip the high limit aquastat. The circulator(s) operates as long as the thermostat(s) calls for heat, provided the water temperature is above the low limit aquastat setting (Figure 23).

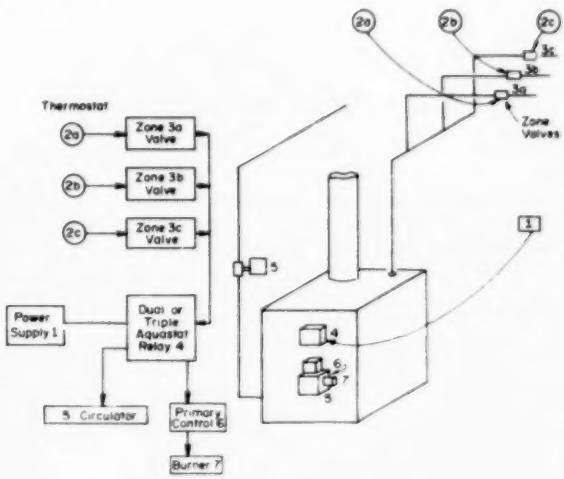


FIGURE 23: MULTI ZONE SYSTEM – USING ZONE VALVES

Boilers with Tankless Coils

Boilers, which also heat domestic hot water with a tankless coil, must always maintain sufficient water temperature to provide domestic hot water. Since the temperature required for domestic hot water is less than that required for heating, the boiler should be allowed to cool to a temperature about 10°F (6°C) lower than the low limit circulator control before the burner starts. When this happens the burner will automatically come on whether or not a thermostat calls for heat. The burner raises the water temperature by a preset amount, usually 15°F to 40°F (8 to 22°C) before it shuts off.

Controlling Temperature Override

Systems with cast iron boilers and radiators frequently experience "temperature override" in spring and fall. These systems contain a large volume of water. Once heated, they take a long time to cool and often heat the home beyond the thermostat's temperature setting.

A common method of controlling override in one zone systems is to control the circulator solely with the aquastat rather than the thermostat and the aquastat. The circulator will run almost constantly provided the water temperature is above the low aquastat setting. The thermostat will cycle the burner.

In colder weather, the burner will run more frequently and for longer periods. The circulator will continue to operate even when the thermostat is not calling for heat, delivering a reduced amount of heat and levelling indoor temperature. During mild weather the boiler temperature will fall so low as to cause the circulator to stop. With this control method, the boiler water temperature will vary according to the outside air temperature.

Control System Components

Controls are designed to operate equipment in the most efficient and safe manner. To effectively use controls, the operator must understand their function.

A few control components are standard to nearly all heating systems. Thermostats, which are really just low voltage switching devices, are one such component. Relays are also standard. They use low voltage on-off signals to control large electrical loads such as burner motors.

Relays are used to perform a specific task if pre-determined conditions are present. They form a logic circuit much like those used in computers. A relay, for example, is often used to turn on a circulator when it senses the thermostat is calling for heat and the boiler water temperature is above a certain level. Relays are often found in individual control components such as aquastats.

All hydronic heating systems have a primary control to stop the burner if the flame fails to ignite. While this important safety feature does not directly heat the home, all electrical commands sent to the burner must pass through the primary control.

Thermostats come in many shapes, sizes and prices.

Better quality thermostats have sealed contacts, usually in a glass bulb bridged by a drop of mercury and mounted atop a bimetallic spring. As the thermostat's circular bi-metal spring rotates with temperature changes, the glass bulb tips, causing the mercury in the bulb to move from one end to the other, bridging the contact and completing the circuit. Good quality thermostats also have a built-in heat anticipator. It must be set to match the electric current rating of the primary control for the oil burner. The higher settings will result in longer running time for the burner and fewer cycles per hour (Figure 24).

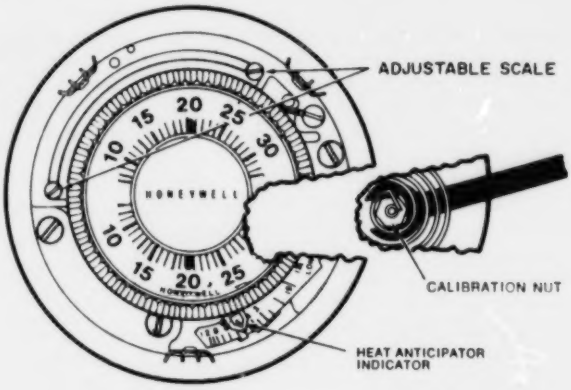


FIGURE 24: ROOM THERMOSTAT

Clock Thermostats automatically lower and raise the temperature settings at pre-selected times, resulting in measurable savings. A working couple, for example, can program their thermostat to raise the temperature in the living area to 68°F (20°C) at 7:00 a.m.; reduce it to 60°F (16°C) at 8:30 a.m., increase it to 68°F (20°C) at 4:30 p.m., and drop it back to 60°F (16°C) at midnight. A program can produce measurable savings depending on the design of the heating system, hours of setback, type of radiation and the energy efficiency of the building. Generally, a night setback over eight hours will produce savings in the 10 to 14 per cent range.

The user can override most of these pre-programmed schedulers simply by pressing a button. Most have a battery to keep the timing device operating for several hours should a power failure occur (Figure 25).

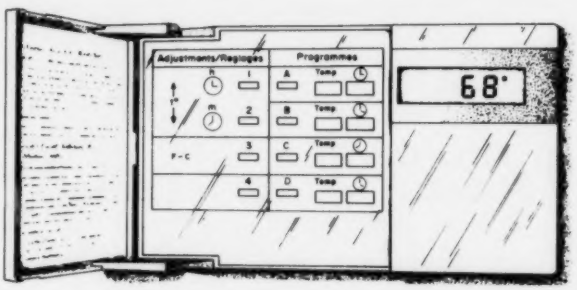


FIGURE 25: CLOCK THERMOSTAT

Aquastats The aquastat is basically a switch activated by a temperature change in water. A high limit aquastat is generally used as a safety device to open a circuit at a preset temperature. As a common example, an aquastat set at 200°F (93°C) cuts the electricity to the burner when the boiler water reaches this temperature. A reverse-acting aquastat has an opposite function, turning on a device, such as a circulator, at a preselected temperature.

Some aquastats operate at a preset temperature. Most have variable temperature settings. Consult the manufacturer's manual before changing the settings on variable aquastats.

Strap on Type aquastats are the simplest type. They are mounted on the surface of a pipe or tank. Because they depend on surface contact only, they are not as accurate as immersion aquastats. Their main advantage is that they can be installed without draining the pipe or tank. They are also less costly.

Immersion Aquastats are more accurate because the sensing element is immersed in the boiler water. They provide a much faster response than the surface mounted type. Aquastats may be horizontal or vertical, depending on the application. Universal aquastats can be mounted in either position (Figure 26).

Dual Aquastats are usually installed where there is a limited number of openings in the boiler and more than one control function is needed. These controls can provide high temperature limit protection and circulator control.

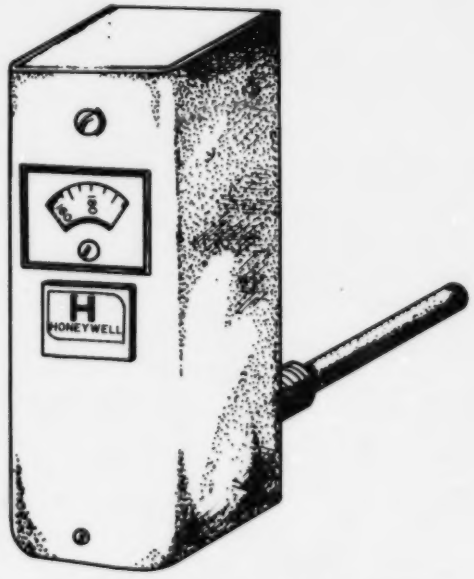


FIGURE 26: IMMERSION AQUASTAT

Triple Aquastat Relays (Figure 27) are normally used on heating boilers with a tankless domestic hot water heating coil. These controls perform three functions: high limit protection with low limit and circulator control. The low limit circulator control cycles the burner on and off, maintaining minimum water temperature for domestic hot water. The circulator control prevents the circulator from operating when boiler water temperature is too low to satisfy both domestic water and heating needs. When the thermostat calls for heat, the triple aquastat operates the burner and, if the water temperature is above the low limit setting, it also activates the circulator.

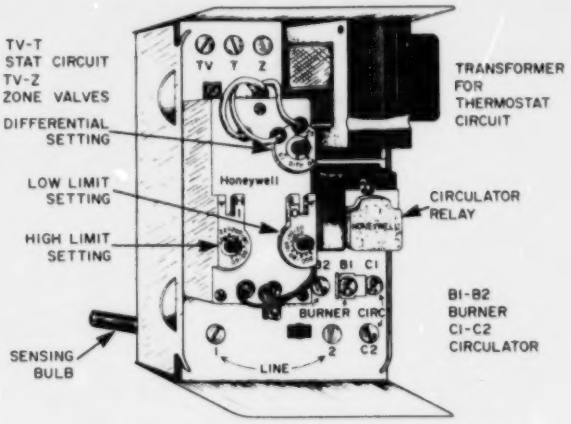


FIGURE 27: TRIPLE AQUASTAT RELAY

Many of these controls have an adjustable differential setting. A differential of at least 20°F (11°C) between the high and low limits is usually recommended with baseboard installations (Figures 28 and 29).

Primary Control on any heating system is the most important because it serves a major safety function. It shuts off the burner within 45 seconds of start-up if a flame is not established, preventing any build up of oil in the combustion chamber and a possibile fire.

Most of the older systems were equipped with a stack mounted primary control. A spiral bimetal helix inside the breeching rotates slightly as it is heated, and establishes a run position. If the flame fails to ignite or goes out, the helix senses the low temperature and the power to the burner will be cut off (Figure 30).

Modern combustion equipment has a primary control, known as a cadmium sulphide cell, mounted in the burner blast tube. The light from the flame activates it. These devices are energized whenever the burner is operating. This is known as "constant ignition". Many older types of stack relays work intermittently, providing ignition only on start-up.

The cad-cell system has no moving parts and is less prone to malfunction (Figure 31).

Today's control systems are becoming more reliable and control failure is less frequent.

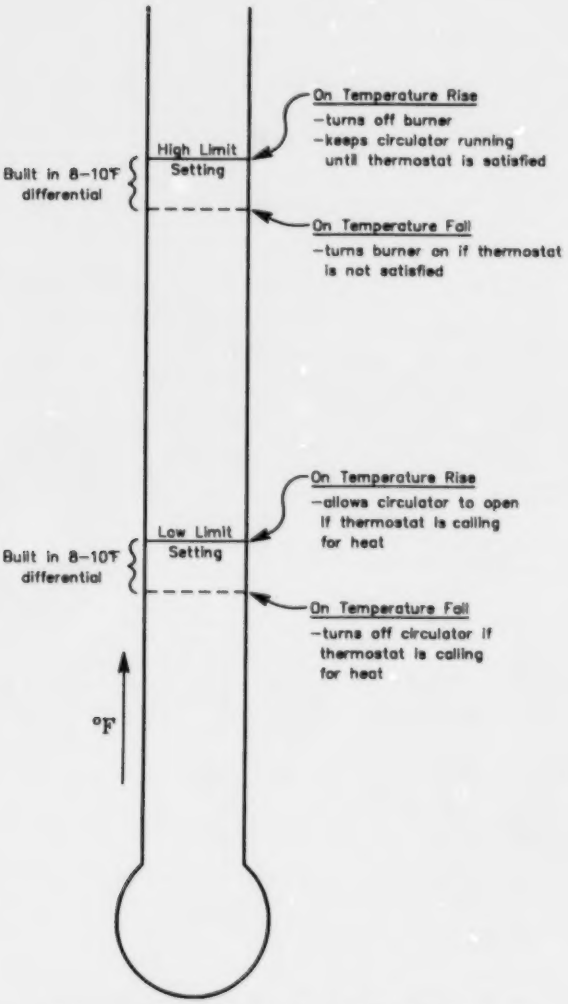

On Temperature Rise
-turns off burner
-keeps circulator running until thermostat is satisfied
High Limit Setting
Built in 8-10°F differential
On Temperature Fall
-turns burner on if thermostat is not satisfied
On Temperature Rise
-allows circulator to open if thermostat is calling for heat
Low Limit Setting
Built in 8-10°F differential
On Temperature Fall
-turns off circulator if thermostat is calling for heat
°F

FIGURE 28: DUAL AQUASTAT OPERATION

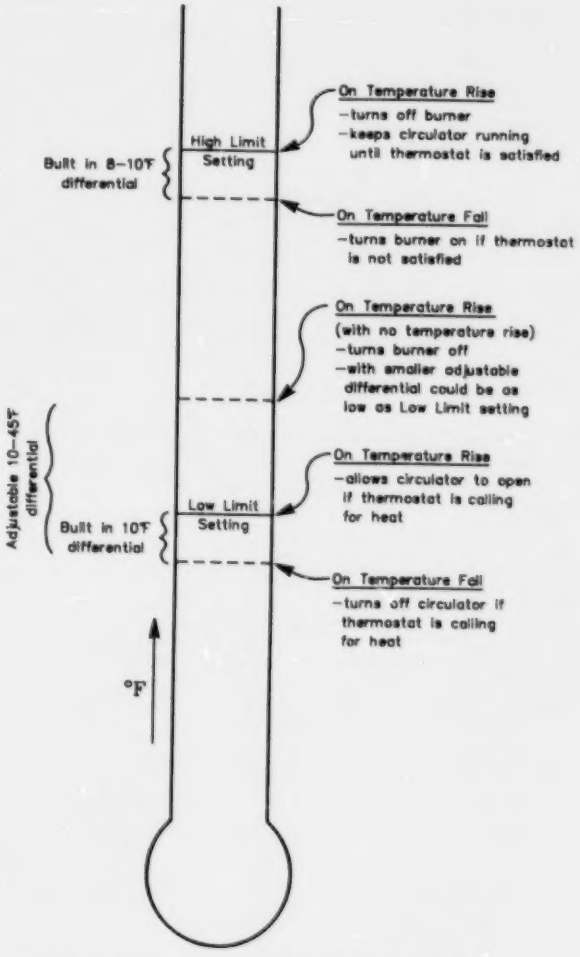

On Temperature Rise
-turns off burner
-keeps circulator running until thermostat is satisfied
High Limit Setting
Built in 8-10°F differential
On Temperature Fall
-turns burner on if thermostat is not satisfied
On Temperature Rise
(with no temperature rise)
-turns burner off
-with smaller adjustable differential could be as low as Low Limit setting
Adjustable 10-45°F differential
On Temperature Rise
-allows circulator to open if thermostat is calling for heat
Low Limit Setting
Built in 10°F differential
On Temperature Fall
-turns off circulator if thermostat is calling for heat
°F

FIGURE 29: TRIPLE AQUASTAT OPERATION

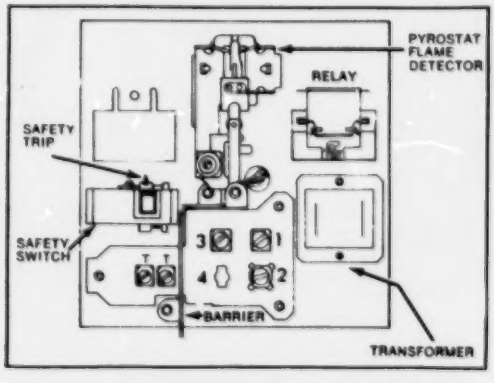


FIGURE 30: STACK MOUNTED PRIMARY CONTROL

Maintenance Considerations

Much like the distribution system, the control system requires little maintenance. With correct temperature settings on the aquastat(s) and properly working valves, the control system should perform satisfactorily.

Retrofit Considerations

Improvements to the control system can enhance comfort and reduce costs.

- **Temperature override** — this common problem in cast iron systems can be reduced by installing an aquastat to vary boiler water temperature to respond to outside air temperatures. Alternately, the circulator can be controlled with an aquastat rather than a thermostat as previously mentioned.

- **Thermostat upgrading** — thermostats with anticipators should replace models without them to reduce temperature swings in the home. Clock thermostats can produce measurable savings for almost all applications. They are even more cost effective in an unzoned system.

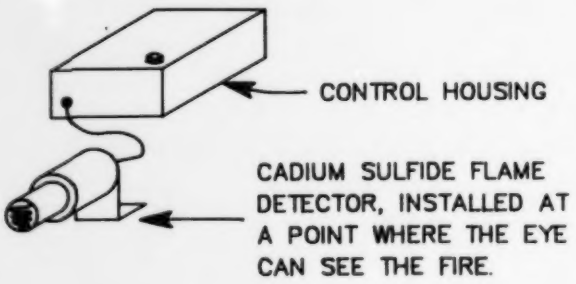


FIGURE 31: CADIUM SULFIDE FLAME DETECTOR

PART FIVE

THE BOILER

Introduction

A boiler is simply a pressure vessel designed to transfer heat released by combustion to a liquid. (In a warm air system, the furnace serves a similar function, transferring the heat released by combustion to air.) Boilers must be constructed to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Codes. Domestic and small commercial boilers are classified as low pressure. Controls and relief valves to limit temperature and pressure must be installed to ensure safe operation.

Types of Boilers

Boilers can be classified by construction and design.

Cast iron boilers: Cast iron boilers consist of individual sections stacked horizontally like donuts (Figure 32) or arranged vertically like slices of bread (Figure 33). The sections are filled with water and contain large openings for the flue gases to pass through. Nipples and gaskets join the sections to permit water to circulate between them. They are held together with long threaded rods and nuts.

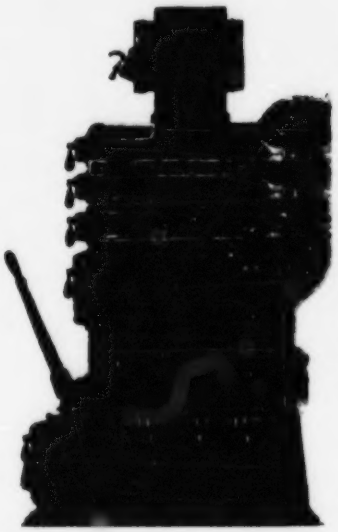


FIGURE 32: OLD STYLE CAST IRON BOILER HORIZONTAL SECTION

The heat output of the boiler is determined by the surface area of the sections exposed to the hot combustion gases. In some boilers, the flue gases pass through each section more than once. In these "multiple pass" boilers, the heat output and efficiency increases. Multiple pass boilers may appear smaller but their heat output may be as high or higher than larger single pass boilers.

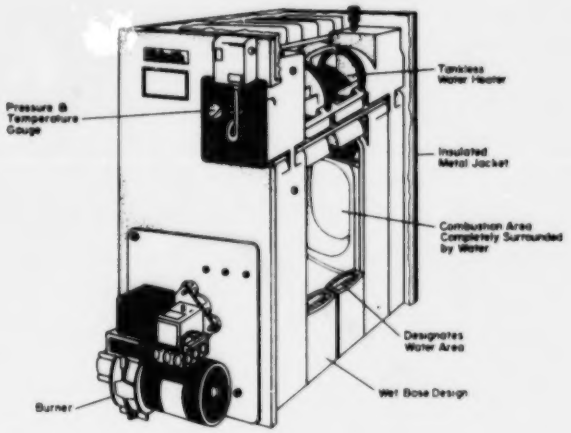


FIGURE 33: CAST IRON BOILER VERTICAL SECTION

Steel boilers: Steel boilers are manufactured from flat or cylindrical plates and tubes welded to form a leak-proof vessel for the water, and an air-tight passage for the combustion gases. The gases usually pass through tubes immersed in water in residential and small industrial boilers. These "fire tubes" may be positioned vertically (Figure 34), or horizontally (Figure 35).

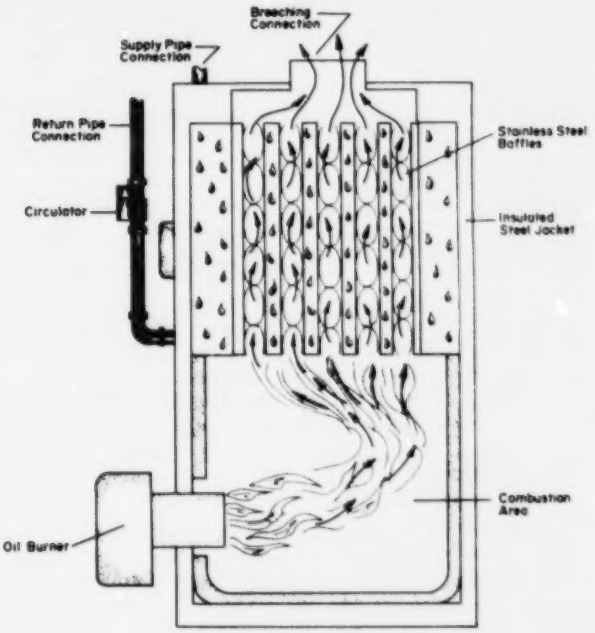


FIGURE 34: VERTICAL TUBE STEEL BOILER

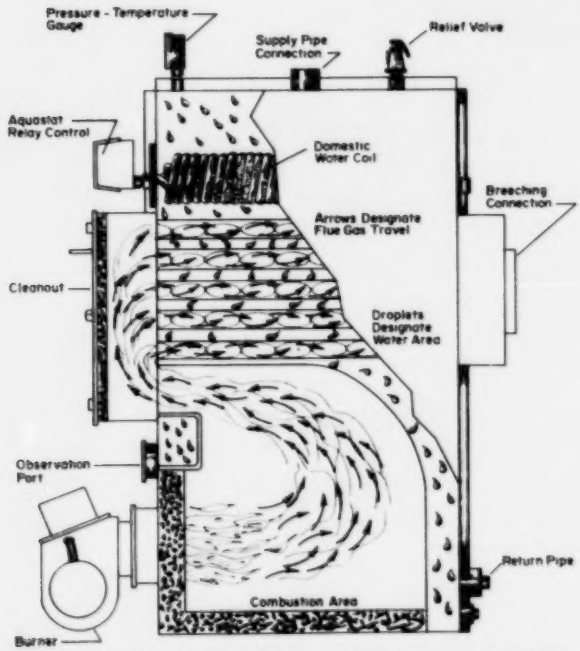


FIGURE 35: HORIZONTAL TUBE STEEL BOILER

Each tube contains a removable spiral shaped piece of steel called a turbulator. The turbulators force the flue gases to scrub the inside of the tube, increasing the heat transfer. This decreases the flue gas temperature and increases the heat transfer efficiency.

Water Passages

Boilers contain water in a number of different ways. Cast iron boilers are often of the wet base design. These boilers hold water above, below, and on the sides of the combustion chamber. Horizontal tube steel boilers often have a wet back design in which water is stored behind and above the combustion chamber. Some steel boilers, called wet leg design, have water passages beside and above the combustion chamber. Most vertical tube steel boilers are a dry base design and store water only above the combustion chamber.

The wet base, wet leg, and wet back designs have a large area of water-filled passages in contact with the combustion chamber area. This increases heat transfer and improves boiler efficiency. A large water capacity boiler is critical when replacing a boiler in a cast iron radiation system. The large water volumes in these systems make a boiler with a large water storage capacity essential for efficient operation.

Combustion chamber

The combustion chamber is a critical but often overlooked part of the boiler. Properly designed, it will radiate sufficient heat to the flame to completely vaporize the fuel, increasing combustion temperatures and producing more complete combustion.

Both the size and shape of the combustion chamber are important. The chamber must be large enough so fuel oil droplets burn before they hit the side of the chamber. Otherwise, soot deposits will form. An oversized chamber or one with deep corners will be too cool, diminishing the radiant heat reaching the flame and lowering overall combustion temperatures.

Most combustion chambers are made of refractory material, such as refractory brick, precast refractory or a low density, low conductivity refractory. A few combustion chambers are made of stainless steel.

Many cast iron boilers converted from coal to oil have combustion chambers from fire brick built in place. This reduces the size of the combustion chamber, producing hotter combustion.

Many boilers use a precast chamber supplied in interlocking sections. Boiler, oil burner and oil burner nozzle manufacturers provide specific information on sizes and shapes of combustion chambers. These include the necessary dimensions based on the firing rate (nozzle size) and the flame pattern of a specific burner.

The most popular refractory today is made of soft fiber. Tests have shown that these chambers can reduce heat loss by up to six per cent when compared with the conventional hard fire brick. A common type of chamber manufactured from ceramic fiber is sold in a plastic bag. When installed, the wet pliable material can be formed by hand to the required shape. These soft refractories also absorb noise — an advantage with sometimes noisy flame retention burners (Figure 36).

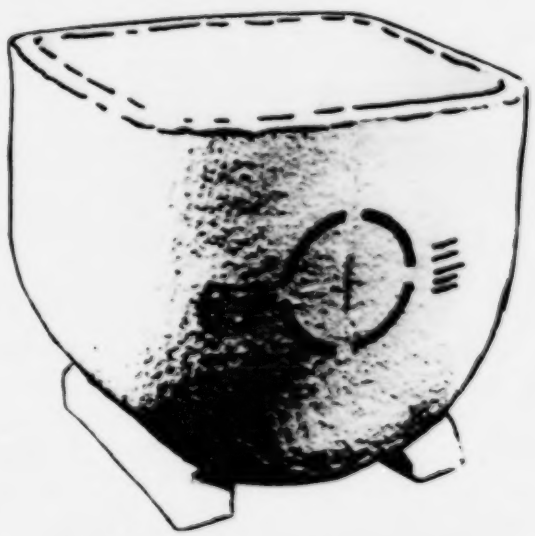


FIGURE 36: COMBUSTION CHAMBER

On dry base boilers, the space between the outside of the refractory and the steel or the base of the boiler should require a high temperature insulation such as mica pellets.

Several manufacturers now market wet base boilers which operate in combination with a high efficiency burner and do not have a combustion chamber. The flame burns in suspension.

Oil Fired Burners

As stated at the beginning of this manual, there are a number of good publications on the design, operation and maintenance of oil burners. Since the proper maintenance and adjustment of the burner requires the special equipment and knowledge of a burner technician, the following description of the burner will be brief and general.

All oil burners in today's residential heating systems use a high pressure, gun-type design. An electric motor (usually 1750 or 3500 rpm) drives a squirrel cage blower and oil pump through a common shaft. The oil pump pressurizes the oil to about 100 psi (690 kPa). The oil flows down a tube to the burner nozzle which sprays the oil in a conical pattern. Each nozzle is specified by the angle of the cone, the distribution pattern of the oil within the cone and the quantity of fuel which will flow at 100 psi in one hour.

The oil nozzle is positioned within a pressed steel or cast iron end cone. It mixes the combustion air from the squirrel-cage blower with the oil spray from the oil nozzle. The air and oil burn when a pair of electrodes connected to a transformer provide a spark. When the air, oil and spark combine correctly, complete and intense combustion takes place.

The end cone of the modern flame retention burner significantly rotates the air entering the combustion chamber. The result is a more thorough mixing of air and fuel in the chamber and a more compact, hotter flame. Combustion temperatures with these burners can be 100 to 200 degrees F (56° to 110°C) hotter than with conventional burners (Figure 37).

The most recent burners to reach the market promote even more complete combustion. These new burners incorporate changes to reduce sooty deposits around the nozzle. These are created at the beginning and end of each burner on/off cycle.

Air flow is established through the boiler before oil is introduced to promote complete combustion. At the end of each cycle, the oil supply is cut off before the blower stops to purge the boiler of combustion products. When the burner is not operating, a damper closes, preventing room air from entering the boiler and therefore reducing heat loss up the chimney.

Boiler Pressure

The maximum and minimum boiler pressure must be regulated to ensure safe and efficient operation of the boiler. Maximum boiler pressure is limited by a pressure relief valve while minimum pressure is maintained by a feed-water regulator.

Pressure Relief Valve: This valve protects the boiler and the distribution system from pressures that could cause the system to rupture. These valves are normally set at the factory to open at 30 pounds per square inch pressure (207 kPa) on a residential hydronic heating system.

The valves consist of a diaphragm or plunger and a spring. When the pressure on the plunger is sufficient to overcome the force of the spring, the valve opens, discharging hot water. Once the pressure drops, the valve closes.

The valve should be installed close to or in the top of the boiler. A shut-off valve must not be installed between the relief valve and the boiler. The drain line from the relief valve must be as large as the discharge opening. Attached to each relief valve is a metal tag indicating the certification standard and rating of the valve in Btus per hour. This rating must equal or exceed that of the oil burner nozzle (Figure 38).

Feed-Water Regulator: When the boiler is cool, the water in the heating system must remain under pressure, otherwise the radiation in the upper levels of the building will not remain filled with water.

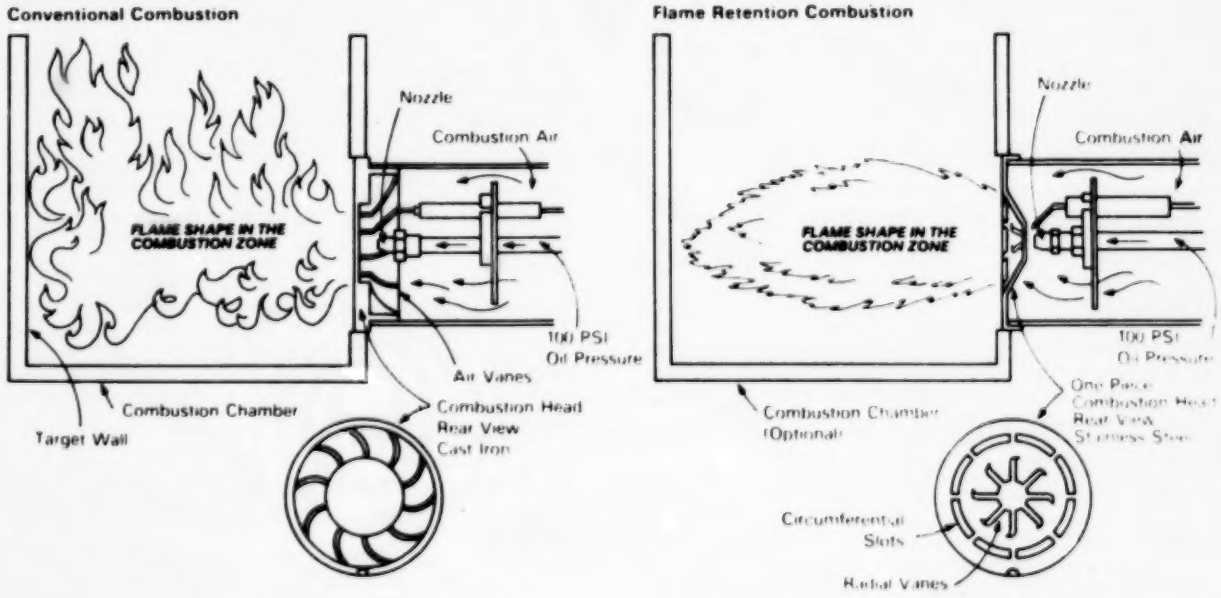


FIGURE 37: CONVENTIONAL AND FLAME RETENTION OIL BURNERS

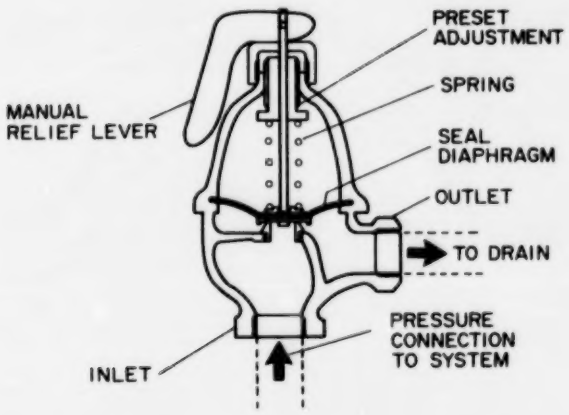


FIGURE 38: PRESSURE RELIEF VALVE CROSS SECTION

The feed-water regulator determines the minimum water pressure. Installed in the supply line from the domestic water line to the boiler, the regulator reduces the line water pressure to the minimum operating pressure of the heating system. The regulator introduces additional water to the system whenever the pressure falls below the desired minimum pressure.

Most of the one-half and three-quarter inch (129 and 190 mm) regulators are set at 12 p.s.i. (83 kPa), a setting sufficient for the average two-storey home. Higher settings are required for taller buildings. The water supply should also include a check valve between the boiler and the feed-water regulator to ensure boiler water does not flow back from the boiler to the domestic water line should the boiler water pressure exceed the domestic water pressure.

A shut-off valve, usually a low cost valve, on the supply side of the feed water regulator makes repairs to the system easier by providing a simple method of turning off the water supply when draining the heating system.

Boiler Expansion Tanks

All hydronic heating systems must include a way to control changes in boiler water volume produced by temperature changes. Older homes may have a tank located above the highest piece of radiation. The tank usually has a manually operated fill valve and a sight glass.

As long as the tank contains water, all the radiators will contain water. The main disadvantage of these tanks is the need for manual filling when the system needs water. Systems with these tanks have low operating water pressure. This limits operating temperatures and increases the chance of air collecting in the radiators.

Most new systems use an expansion tank located adjacent to and above the boiler. All these tanks contain both air and water. As the water in the system heats and expands, water is pushed into the expansion tank and compresses the air in the tank, raising the pressure (Figure 39). Newer expansion tanks may have a diaphragm which separates the air and water (Figure 39a). Over the heating season, the water absorbs the air in those tanks which do not contain a bladder. When this happens, the tank is referred to as water-logged and must be drained.

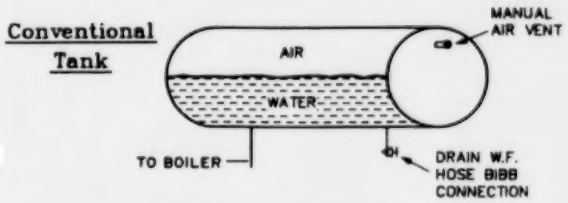


FIGURE 39: EXPANSION TANKS

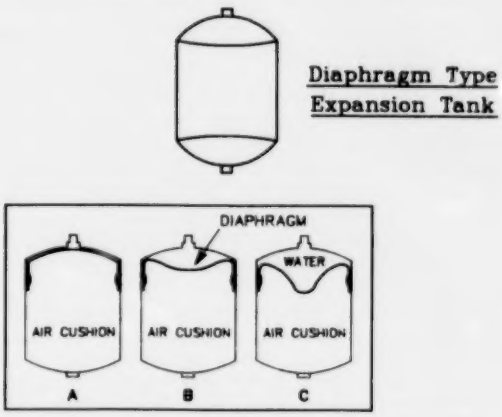


FIGURE 39A: DIAPHRAGM TYPE EXPANSION TANK

If the tank is not drained, pressure may rapidly increase in the system until the pressure relief valve is activated, discharging hot boiler water. When the pressure drops, the feed water regulator may introduce more water into the system and the cycle will repeat itself.

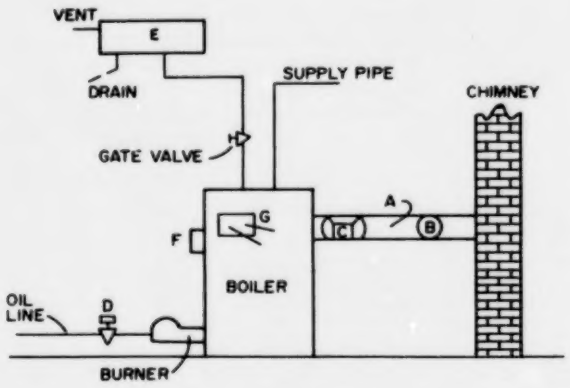
Those expansion tanks which contain a diaphragm eliminate water logging and permit the pressurizing of the air side of the tank before installation. This allows the use of a smaller tank.

In newer homes with baseboard systems, the water volume is small, therefore the expansion tank can also be small. In large systems with free standing cast iron radiators and large water volumes, the size of the expansion tank is more critical because the changes in water volume caused by thermal expansion are much greater.

Some of the old cast iron gravity systems have an expansion tank open to the atmosphere, located high in the building. Atmospheric pressure tanks should be replaced with pressurized units. Appropriate pressure-reducing feed valves should be installed.

Additional Boiler Components

Homeowners can add several devices to the combustion side of the heating system to control or improve its operation and efficiency (Figure 40).



(A) BREECHING
(B) BAROMETRIC DAMPER
(C) STACK DAMPER
(D) DELAYED ACTION OIL VALVE
(E) AIR CUSHION TANK
(F) CONTROL (TEMP SETTING)
(G) INTERNAL TANKLESS HEATER

FIGURE 40: ADDITIONAL BOILER COMPONENTS

Barometric Dampers: The barometric damper, or draft regulator as it is sometimes called, is now standard on all oil systems. It maintains a constant draft within the combustion chamber. Draft is created by the column of warm combustion gases rising up the chimney.

The intensity of the draft is primarily determined by the temperature of the gases, the height of the chimney and the number of air leaks present. Such factors as wind and outside air temperature can also be important.

DRAFT CONTROLS

FIGURE 41: BAROMETRIC DAMPER

The barometric damper is an adjustable counter-balanced flapper which opens or closes to maintain constant draft over the fire. When conditions cause the draft to increase, the flapper opens to admit air from the home, reducing draft. When the natural draft decreases, the flapper closes, maintaining the draft at the desired level (Figure 41).

Stack dampers: Boilers can have an electro-mechanical device called a stack damper installed in the breeching leading from the boiler to the chimney to reduce standby heat loss.

When the burner is off, the device closes in the breaching, preventing heated air from passing through the boiler and up the chimney. This air cools the boiler and increases overall oil consumption. Safeguards must be incorporated in the design to ensure these dampers open before the burner ignites.

Stack dampers are often installed on large cast iron boilers converted from coal to oil because the large passages in these boilers allow a significant amount of air to pass through and up the chimney when they are not operating. This produces a modest saving by reducing stand-by heat losses up the chimney (Figure 42). Several new makes of burners contain an internal damper that serves the same function as the stack damper.

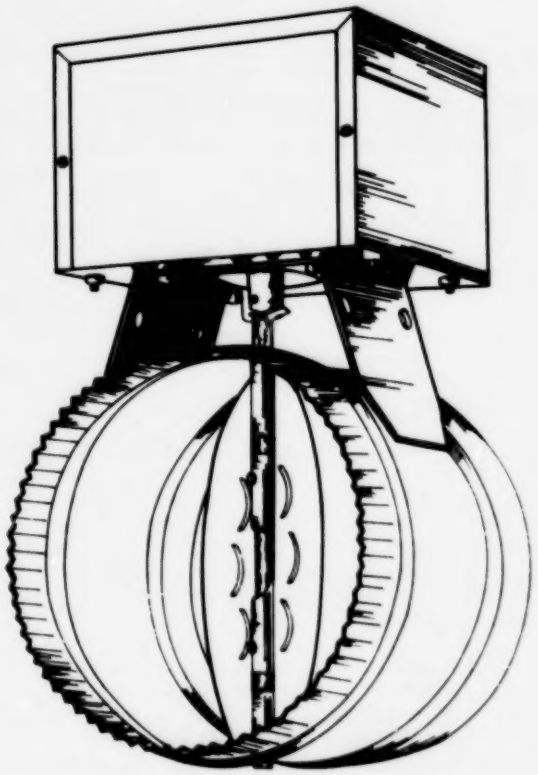


FIGURE 42: STACK DAMPER

Delayed Action Oil Valves: These valves keep oil from entering the burner until air flow is established through the burner and the combustion chamber. This ensures clean combustion.

When the thermostat calls for heat, the burner motor starts, operating the blower and the pump. A delayed action oil valve withholds the introduction of oil for three to eight seconds. When the valve opens, the flame is instantly established and the products of combustion proceed through the boiler and up the chimney.

Without this valve, initial ignition of the flame often takes place in a stationary, oxygen deprived environment, resulting in a few seconds of incomplete combustion each time the burner starts. This can foul the heat exchanger surfaces and impair heat transfer. When the burner shuts off, the valve immediately closes to prevent any droplets of oil from entering the combustion chamber (Figure 43).

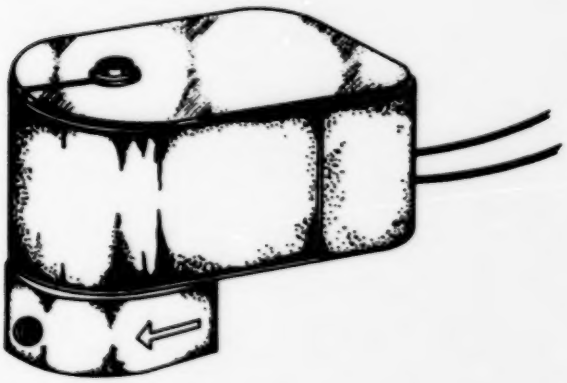


FIGURE 43: DELAYED ACTION OIL VALVE

Domestic Water Heaters: Boilers can also heat domestic water with a tankless coil. These tankless coils, or indirect heaters as they are sometimes called, transfer heat from the water in the boiler to the domestic hot water (Figure 44).

They come in two types: internal heaters and external heaters. The internal heater, as its name implies, is fitted in the boiler. The external heater, usually called a side arm heater, is more common in older systems. Encased in a shell, the side arm heater circulates the boiler water through the shell and transfers heat to the coil carrying the domestic water. These systems use a storage tank located above the boiler. These tanks should be insulated. In both systems, boiler water and domestic water remain in separate circuits. They never mix.

The tankless heater must have a large heating surface to supply hot water instantly and in sufficient quantities to handle peak loads. When sizing a tankless heater, pressure drop, volume of water, boiler load, and recovery rate must be considered. Coils are normally supplied in either three, four, or five gallon (13 to 22 l) per minute capacities. Some systems use a storage tank located above the boiler.

A thermostatic mixing valve should always be installed to limit domestic hot water temperature, thereby conserving hot water and eliminating the possibility of scalds from excessively hot water. These valves add cool water to the hot water to maintain the desired temperature for domestic water (Figure 44a).

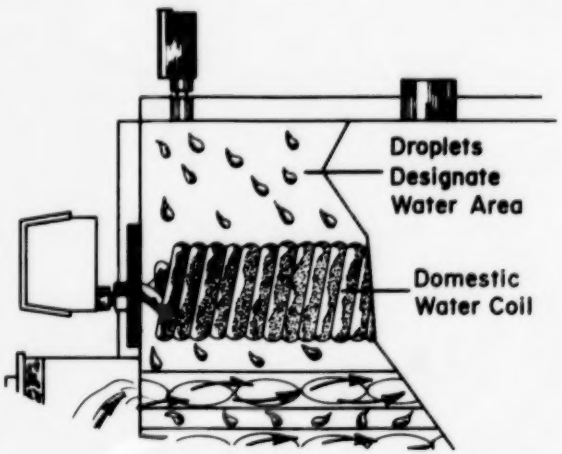
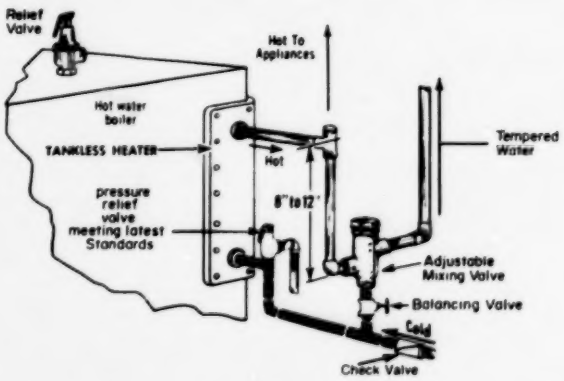


FIGURE 44: TANKLESS DOMESTIC WATER HEATING COIL IMMERSED IN BOILER WATER



Typical piping arrangement for the installation of a domestic water mixing valve. It is most important that the valve be installed at the specified distance below the hot water outlet as shown.

FIGURE 44A: TANKLESS HEATER AND THERMOSTATIC MIXING VALVE

Boiler Water Temperature Setting

The water temperature settings on the controls of an oil-fired, hydronic boiler depend largely on the type of radiation units involved and the presence of a tankless water heater.

Convection Systems: Convector heating systems, whether baseboard or cabinet type, should have water supplied at 180° to 200°F (82° to 93°C). If the radiation output is marginal or slightly undersized, the high limit on the aquastat may have to be set at 210°F (99°C).

Convector radiation requires these higher temperatures because it relies only on convection currents. Water at 160°F (71°C), for example, may not provide satisfactory results during extremely cold weather.

Most control manufacturers recommend the setting of the high limit aquastat 20°F (11°C) higher than the circulator aquastat on dual or triple aquastat controls. On triple aquastats, the low limit is usually set at 140°F to 170°F (60 to 77°C) to ensure the availability of sufficient domestic hot water. Follow the manufacturer's recommendations for temperature settings.

Cast Iron Systems: Free standing cast iron radiators will function quite effectively with much lower water temperature since heat energy is also provided by radiation. Water temperatures in these instances can range upwards from 140°F (60°C).

The water temperature will vary greatly on older systems with free standing cast iron radiation, continuously operating circulators, and thermostats that only operate the oil burner. In mild weather, the thermostat may be satisfied and turn off the burner when the water has reached only 120°F (49°C). In cold weather, the water temperature may reach 160°F (71°C) or 170°F (77°C). This type of system is described in greater detail in Part Three — Distribution.

Maintenance Considerations

Oil-fired hydronic boilers must be maintained annually. The quality of the annual servicing depends largely on the thoroughness of the technician. The care taken during the following procedures will significantly effect annual heating costs.

- **Annual Cleaning** — The combustion chamber, flue passages, fire tubes and all heat exchange surfaces should be thoroughly cleaned of soot and residue. The breeching should be removed and cleaned as well.

This annual cleaning is carried out with an industrial vacuum cleaner and a variety of wire brushes.

The burner, including the blower wheel and blower housing, should be carefully inspected and cleaned. The oil nozzle must always be replaced with a new nozzle of appropriate size and flame pattern. It is not advisable to clean or reuse an old nozzle.

Often the oil nozzle is oversized, especially in homes with added insulation or otherwise reduced heat loss. Consideration should be given to downsizing in such instances.

The technician should check the ignition electrodes for hairline cracks in the porcelain insulators. The tips should be accurately located relative to the oil nozzle and in accordance with the oil burner manufacturer's recommendations. Check the condition of the combustion chamber. The size and shape of the combustion chamber should also be verified if the burner nozzle size has been changed. The location of the burner should also be checked relative to the combustion chamber.

When the boiler and burner are reassembled and fired, the draft should be checked and the barometric damper reset if required.

The fuel lines should be examined for leaks and the filter cartridge(s) replaced. (Old style reusable oil filters should be replaced with spin-on, disposable filters, because they filter-out much finer particles).

With cad-cell primary controls, the cell should be wiped clear. Bimetallic primary controllers should be wiped clean. The reassembled boiler should then go through a complete operation sequence to check the controls.

FIGURE 45: EFFICIENCY TEST REPORT FORM

EFFICIENCY TEST REPORT FORM

BEFORE

Efficiency (%) _____ Poor | Fair | Good | Excellent
60 70 80

Smoke _____ Acceptable | Unacceptable
0 2 4 6

CO_2 (%) _____ Poor | Fair | Good | Excellent
6 8 10 12 14

Net Stack Temperature (°F) _____ Excellent | Good | Fair | Poor
400 500 600 700 800

Overfire Draft ("H_2O) _____

Breech Draft ("H_2O) _____

AFTER

Efficiency (%) _____ Poor | Fair | Good | Excellent
60 70 80

Smoke _____ Acceptable | Unacceptable
0 2 4 6

CO_2 (%) _____ Poor | Fair | Good | Excellent
6 8 10 12 14

Net Stack Temperature (°F) _____ Excellent | Good | Fair | Poor
400 500 600 700 800

Overfire Draft ("H_2O) _____

Breech Draft ("H_2O) _____

DATE _____ 19 ____ CERTIFIED TECHNICIAN _____

• **Efficiency Test** — Finally, a qualified technician should conduct an efficiency test to achieve the maximum performance from the boiler. Burners can not be accurately adjusted without performing this test.

The efficiency test involves adjusting the combustion air openings to provide enough air for complete and clean combustion. An excess of air cools the flame and decreases efficiency. The air openings are adjusted to provide the proper smoke number — a measure of clean combustion. The flue gas temperature and carbon dioxide or oxygen in the flue gas are measured, and these numbers used to determine the boiler's efficiency.

If the efficiency reading is low, the technician should recommend ways to improve it. Changing the nozzle size or flame pattern, installing a different burner end-cone or different turbulators are examples of low cost measures that can affect combustion efficiency (Figure 45).

• **Chimneys** — With a well-maintained oil-fired boiler, chimneys usually require little attention. Every five to ten years accumulated soot should be removed. Check the exterior of masonry chimneys annually for deterioration of the brick or mortar. Carry out repairs as required.

• **Expansion Tank** — The conventional air-over-water-type expansion tank should be checked every year for a sufficient volume of air.

If the tank is more than two-thirds full of water while the system is cool (water pressure near 15 psi (100 kPa)), it should be drained and recharged with air (Figure 46).

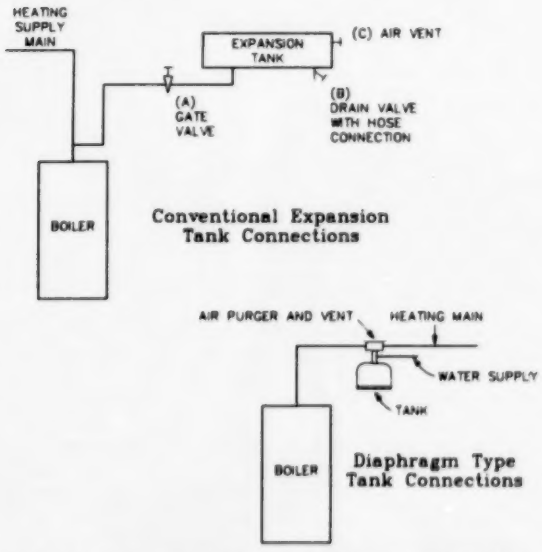


FIGURE 46: EXPANSION TANK CONNECTIONS

To drain the tank, close supply valve (A). Open drain valve (B). After a few minutes, the flow of water will slow. Then, open air vent (C). Allow tank to drain completely. Close drain valve (B) and air vent (C). Open supply valve (A). This lets water back into the tank.

• **Tankless Coil** — In areas with hard water, tankless coils often develop mineral deposits which reduce heat transfer and restrict water flow. A plumber can dissolve these by flushing the coil with an acidic solution.

• **Antifreeze** — Some hydronic systems are filled with an antifreeze solution to prevent freezing. Most codes require the use of non-toxic propylene glycol in case the glycol finds its way into the domestic water supply through the pressure-reducing valve or a leak in the tankless coil. Glycol could contaminate the domestic water supply if the water pressure drops below that of the heating system.

Since propylene glycol's heat transfer characteristics are not quite as good as water's, use only the minimum amount of glycol to provide the desired level of freeze protection. The required ratio of glycol to water will be specified on the glycol container.

The volume of water can be calculated based on the specifications of the system's components. Alternately, the total amount of water in the system can be determined by draining the water into a barrel. Then the appropriate amount of propylene glycol and water for the desired freeze protection can be pumped into the system.

The level of freeze protection and the acidity of the glycol should be checked annually according to the glycol manufacturer's recommendations.

If the heat delivery capability of the system was marginal before the addition of glycol, replace the circulator pump with a larger unit or increase the boiler control temperatures.

Retrofit Considerations

• **Burner/Boiler Replacement**: If the efficiency of the old boiler can not be increased above 70 per cent, the purchase of a new burner or boiler may be advisable. Today's oil burners have seasonal efficiency levels of 80 per cent or more. Their steady state efficiencies are even higher. Replacing an inefficient burner alone can reduce heating costs by 10 to 15 per cent.

Many old cast iron boilers can become reasonably efficient if a new burner is installed. In some cases, the addition of a new burner can make the old boiler as efficient as a modern one.

The experienced heating technician can advise whether the older boiler equipped with a replacement burner or a new boiler/burner combination is most cost effective.

When installing a new burner, the combustion chamber and the burner must be properly matched to ensure that a compact, hot flame is produced.

When replacing a boiler, efficiency, heating capacity and water capacity should be considered.

Boilers are rated according to the amount of heat they can deliver expressed as thousand of Btus per hour (MBH) with a given nozzle. Manufacturers can supply data regarding the instantaneous, and in some cases seasonal efficiency of their boilers, when fitted with certain burners.

A replacement boiler should have a rating slightly higher than the maximum heat loss of the house plus the anticipated hot water load if tankless coils are used. The boiler must not be oversized or inefficient operation will result.

If the boiler replaces a large cast iron boiler in a system with cast iron radiators, the water volume of the replacement boiler is important. In systems where the circulator operates continuously and the boiler does not provide domestic hot water, a small boiler with sufficient heating capacity and good efficiency will be adequate.

If domestic hot water is provided, the boiler must contain a larger water volume. If the water volume is too small, the circulator will cycle on and off as large volumes of cold water enter the boiler from the radiators. A large volume boiler will reduce these changes in water temperature and ensure boiler water remains sufficiently hot to provide domestic water.

PART SIX

STEAM

Introduction

Steam heating systems can be found in some older homes, apartments, and commercial buildings. These systems are readily distinguished from hydronic systems by examining the pipes at the boiler. Steam boilers are connected to the radiation by either one large steel pipe, three or four inches (76 to 101 cm) in diameter, or by one large and one small pipe. On hydronic systems, the supply and return pipes are always the same diameter at the boiler.

Steam heating systems utilize latent heat of vaporization which allows the transfer of a significant amount of energy by a given amount of water at a nearly constant temperature.

One pound of water in its liquid state requires 1 Btu of energy to raise its temperature 1°F. To change that same pound of water from a liquid to a vapor requires about 1000 Btus. The exact amount of energy required to vaporize water depends on the water/steam pressure.

While changing from a liquid to a vapor, the water's temperature remains virtually constant. Water boiling in an open pot can only be heated to 212°F (100°C). In order to raise its temperature further, the pot needs a tight fitting, pressurized lid like that on a pressure cooker. Otherwise, the water remains at 212°F (100°C) until it boils away.

When the boiler is fired, the heat from combustion raises the water temperature until the water boils. As steam is produced, the air above the water is displaced and steam fills the system. Once the system is filled, steam starts to generate pressure. This increase in pressure raises the temperature required to generate more steam until an equilibrium is reached.

Steam which reaches the radiation releases its heat into the home. Once sufficient heat is released, the steam condenses to a liquid called condensate. This condensing of steam causes a decrease in pressure since a pound of water occupies much less space than a pound of steam. This pressure drop causes more steam to flow from the boiler to the radiators. The condensate returns to the boiler and the process is repeated.

Steam Distribution Methods

There are a number of different methods to distribute the steam and return the condensate. The basic possibilities are:

- One pipe, air-vent, gravity return
- Two pipe, air-vent gravity return
- Two pipe, Non-vacuum, condensate pump return
- Two pipe, Vacuum return system, with vacuum pump

One Pipe: The one pipe system is physically the least complex although in its simplest form it is somewhat difficult to visualize. A single pipe is used for both steam supply and condensate return.

Steam leaving the boiler flows along the large diameter (3 or 4 inch) main pipe and then upward through smaller riser pipes into the cast iron radiators. There it releases its heat, changing back to a liquid. This liquid condensate runs back down the same riser pipes to the same main. Since the main gently slopes down toward the boiler, the condensate runs along the bottom of the main while the steam flows above it in the opposite direction.

The main pipe must be carefully sized and sloped to minimize the chance of steam pushing slugs of condensate back through it, causing "water hammer". Water hammer produces a loud, annoying noise and can eventually damage the piping.

Single pipe systems can also form a loop with a single pipe feeding each radiator. In these systems, the steam and condensate travel in the same direction in the downward sloping supply pipe. Steam and condensate flow in opposite directions in the single riser pipes feeding each radiator. (Figure 47 and Figure 48.)

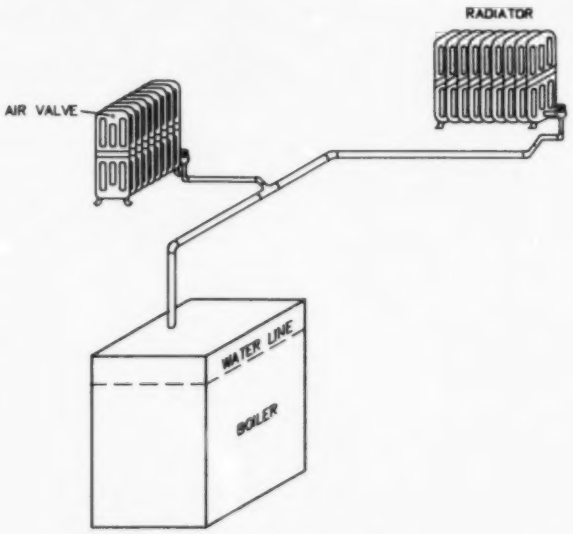


FIGURE 47: SIMPLE ONE PIPE SYSTEM

Two Pipe System: In two pipe systems, separate pipes deliver steam and return the condensate. In addition to air vents, these systems require a device called a steam trap to separate steam from condensate. This ensures quieter operation by preventing steam from entering any of the condensate piping (Figure 49).

Two pipe systems can utilize gravity return, with a wet leg arrangement similar to the one pipe system. If the system pressure is too high for gravity return, condensate can be collected in a tank and pumped back to the boiler.

Large commercial systems sometimes use a vacuum pump to depressurize the entire system, enabling it to run at low temperatures. The vapor systems utilize a central air eliminator to replace separate air eliminators on each radiator.

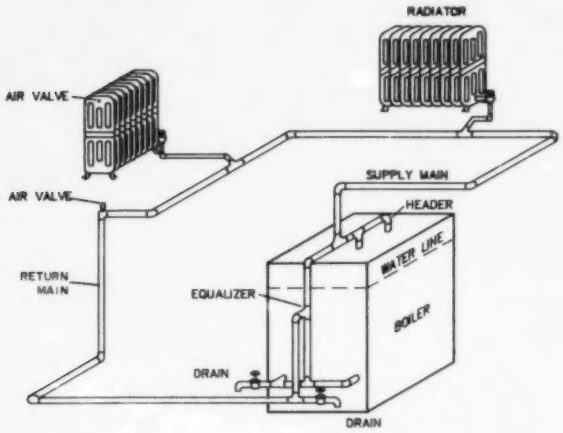


FIGURE 48: ONE PIPE AIR–VENT STEAM SYSTEM

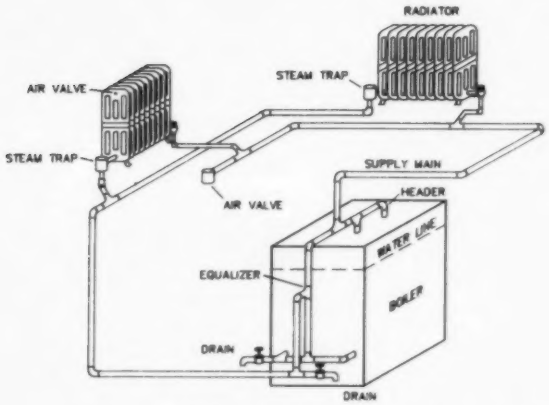


FIGURE 49: TWO PIPE AIR–VENT GRAVITY RETURN SYSTEM

Residential steam systems operate at low pressures. Safety codes require low pressure, unsupervised steam systems to operate below 15 psi (103 kPa) gauge pressure. Most systems operate between a slight negative pressure and 5 psi (35 kPa).

Special Steam System Components

All steam systems have a number of unique components, many of which serve functions similar to their counterparts in hydronic systems.

Safety Relief Valve: All steam systems have a snap action, safety relief valve sized to discharge steam at the maximum rate at which the boiler can generate it. These valves move from the closed position to a full open position within a small pressure range. This prevents the high velocity, escaping steam from damaging the valve seat, preventing its closure.

Pressuretrol: A steam pressuretrol is a burner control device mounted on the steam boiler. Unlike an aquastat, which responds to temperature, a pressuretrol responds to pressure within the boiler. A high pressure pressuretrol will open a circuit, stopping the boiler when a certain pressure is reached (Figure 50).

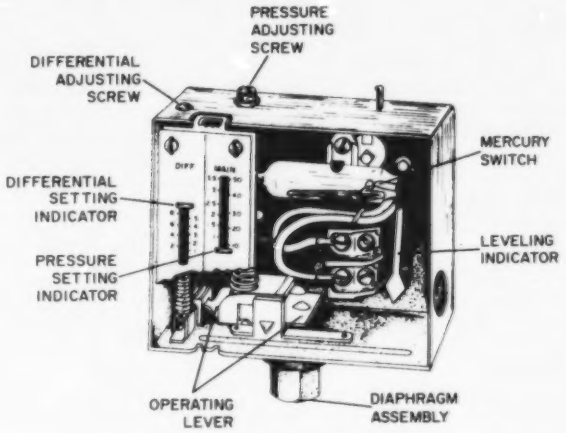


FIGURE 50: PRESSURETROL CONTROLLER

Boiler Water Control: The water level within a steam boiler must be carefully maintained. Boiler water feeders incorporate a float device to add water to the boiler if it is required. There is also a low water level cut off which stops power to the oil burner should the water level become excessively low. If the burner should continue to operate, serious damage would occur (Figure 51).

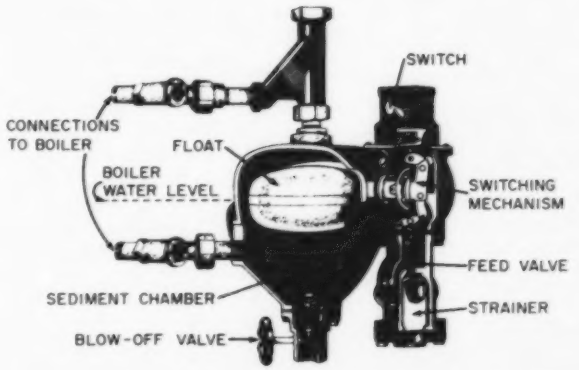


FIGURE 51: WATER AND LOW WATER CUT–OFF COMBINATION CONTROL

Hartford Loop: Most two pipe systems are installed with a "Hartford Loop" piping arrangement on the condensate return line. An equalizing pipe is connected between the steam supply port and the condensate return port on the boiler. The condensate returns to this pipe just below the normal operating water level in the boiler.

If for any reason, the pressure on the condensate line should decrease, water would flow from the boiler until the water level dropped to the same elevation as the connection with the equalizing pipe. This would ensure that some water always remained in the boiler (Figure 52).

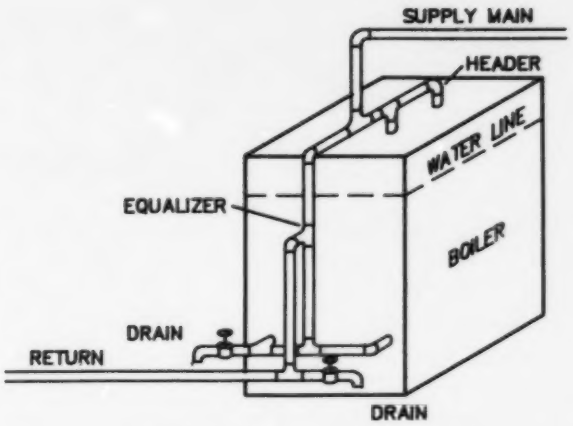


FIGURE 52: HARTFORD LOOP

Air Eliminators: Air and carbon dioxide must be eliminated from any steam heating or serious corrosion and reduced heat delivery will occur. Air vents are located on radiators and at the end of supply mains. These allow air to escape but close when steam starts to escape.

Most designs incorporate some sort of bellows, an element filled with a volatile fluid that vaporizes below the temperature of steam. These devices operate a needle-and-seat valve.

As a steam system starts, air is driven from the radiators through the air eliminator. With the elimination of the air, steam starts to escape, the element will expand, and the valve closes, keeping steam within the system.

Most air eliminators incorporate a float which closes the valve should condensate enter. When cool, a check valve keeps air out of the radiator for several hours allowing the heating system to continue generating steam at reduced pressure and temperature (Figure 53).

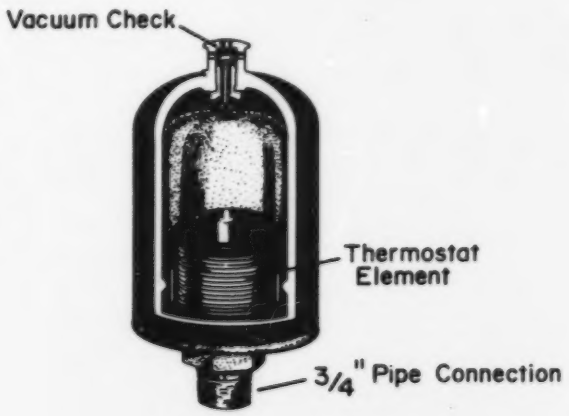


FIGURE 53: AIR ELIMINATOR

Condensate Pump and Receiver: Large steam systems will include a condensate pump and receiver tank. The receiver holds the condensate and the pump pumps it back to the boiler as required. With smaller systems, operating at lower pressure, the condensate flows back to the boiler without a pump. When the steam boiler requires additional water, the automatic float switch on the boiler starts the condensate pump and pumps condensate into the boiler. The total radiation load and the boiler size determines the size of the tank and pump.

Valves: Special globe valves are commonly used on steam heating systems. The valve seat is designed to withstand high pressure and temperature as well as the cutting action of high-velocity steam.

One such valve is located next to each radiator to regulate the flow of steam. These can be manually operated or incorporate a thermostatic device to automatically control the flow of steam for the desired temperature.

Steam Traps

Steam traps are essential to a two pipe system. The steam trap, an automatic valve, allows condensate, air and carbon dioxide, but not steam, to pass from the system. No one type of trap will function in all applications. All traps require careful sizing to handle the condensate load.

The following traps are the more common types for residential or small commercial steam heating systems:

Bellows Thermostatic Trap: The bellows thermostatic trap has a bellows or element that contains a liquid with a lower boiling point than water. When the trap is cold, the element contracts, keeping the discharge port in the open position and allowing condensate, air and carbon dioxide to escape. When steam enters the trap, vapor pressure inside the bellows element is greater than the steam pressure outside, causing the element to expand and close the discharge port. Bellows type thermostatic traps are commonly used in radiators, convectors and small capacity, low pressure systems (Figure 54).

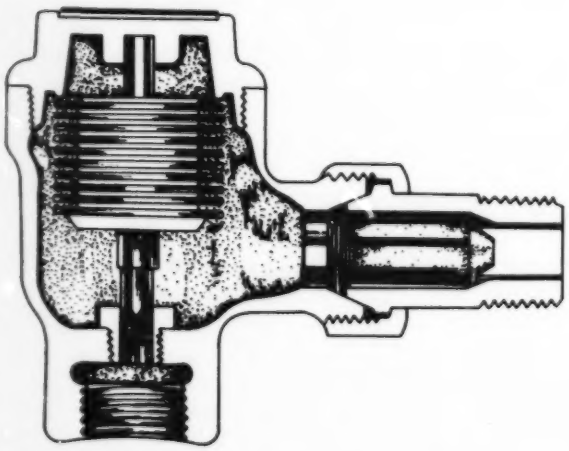


FIGURE 54: THERMOSTATIC TRAP

Float and Thermostatic Traps: The float and thermostatic trap, commonly known as the F & T trap, combines both a float and thermostatic trap in one body. A bellows thermostatic element operates on temperature difference and provides automatic venting. The float portion opens and closes depending on the level of condensate in the trap body.

On start up, the float valve is closed and the thermostatic element open for rapid air venting. This allows the system to rapidly fill with steam. The steam enters the trap body; the thermostatic element closes; the condensate flows in; the float rises; the condensate discharges. The float continuously discharges the condensate at the same rate as it accumulates in the trap. These traps are commonly used at points with a high accumulation of condensate. They respond under a wide range of pressures from zero P.S.I. and up (Figure 55).

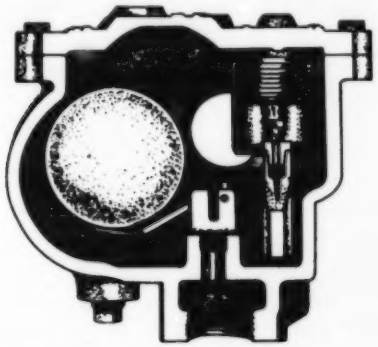


FIGURE 55: FLOAT AND THERMOSTATIC TRAP

Other Traps: Traps such as the inverted bucket, impulse traps, orifice traps and thermo-dynamic or disc traps, should not be used on residential systems. They are designed for commercial and higher pressure applications.

Retrofit Considerations

Steam systems are sometimes converted to hot water to improve temperature control and reduce operating costs. The success of such a conversion and its economic viability depends on the size and arrangement of the radiation and piping. A qualified heating system designer must be consulted before undertaking any conversion.

- **Converting the System** — Cast iron radiators in steam systems are often greatly oversized, enabling them to use lower temperature water.

With single pipe systems, the existing pipe must be replaced with two properly sized pipes. The cost of this major renovation, however, can rarely be justified economically.

If the pipes in a two pipe steam system are appropriately sized, these systems may be suitable for conversion to hot water. Often, the old steam supply pipe is so large that the hot water flow is slow, resulting in excessive heat loss from the pipes instead of the radiation. Similarly, the old condensate return line may be so small that it restricts the flow of return water.

If the radiation and piping sizes are appropriate, conversion of a two pipe system from steam to hot water entails the removal of steam traps and air eliminators and the installation of air vents. Usually the steam radiator control valve can be retained to balance the hot water flows.

Depending on the design, particularly the size and number of fittings, steam boilers can often be converted to hot water by replacing the pressure and water level controls with temperature controls.

- **Replacing the System** — Generally, it makes more sense to replace an unsatisfactory steam system with a new, properly designed hot water system. A new zoned system will result in better temperature control throughout the building. Modern convector baseboard radiation uses a much smaller water volume, resulting in faster response. Modern boilers are more efficient, especially compared to some of the old, converted coal boilers used in steam systems. Replacement will markedly reduce fuel costs.

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